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PHYSICS.—*General survey of certain results in the field of high pressure physics.*[1]

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In this lecture I shall attempt to present a general survey of those parts of the field of high pressure physics with which I have had direct contact, dealing first with technical matters of producing and measuring high pressure, and secondly with the physical phenomena which occur under high pressure.

With regard to technique, several different ranges of pressure are to be recognized. The first step was to devise a method of packing which should be without leak, since leak had limited the range of previous experiments. A packing was devised, shown in Fig. 1, which automatically becomes tighter the higher the pressure, so that any pressure is accessible up to the strength of the containing vessels. If the vessels are made of one-piece construction, from the best heat treated alloy steels, it is possible to reach pressures of 12,000 kg/cm² as a routine matter and on occasion for short intervals of time as high as 20,000. For many years my work was confined to this range, and in this range it proved feasible to measure nearly all the ordinary physical properties of substances. The next step was to give the pressure vessel external support which increases in magnitude at the same time the internal pressure increases. A simple method of doing this is to make the external surface of the pressure vessel conical in shape, and to push it into a heavy collar with a force which increases as the internal pressure increases, as illustrated in Fig. 2. With apparatus of this kind it is possible to make routine experiments up to 30,000 kg/cm² with volumes of the order of 15 cm³, to get electrically insulated leads into the apparatus, and practically to repeat all the former work in the range to 12,000. I am still engaged in carrying out this program. An extension of the same technique on a smaller scale with capacities of the order of 0.5 cm³ can be made up to 50,000 kg/cm². In this range all ordinary liquids freeze solid, electrically insulated leads cannot be got into the apparatus, and the phenomena which can be studied are limited to various volume effects, such as compressibilities and phase changes, including fusions and polymorphic transitions.

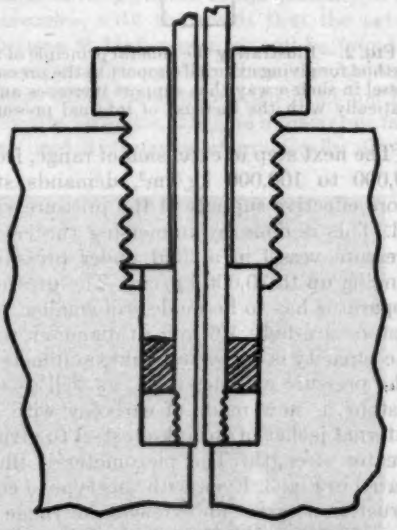

FIG. 1.—The general scheme of the packing by which pressure in the soft packing materials is automatically maintained a fixed percentage higher than in the liquid.

[1] Nobel Laureate Lecture delivered at Stockholm, Sweden, December 11, 1946. Reprinted by permission from the proof of the article for *Les Prix Nobel en 1946*.

The external support of the vessel is only one of the factors that make possible the extension of range from 12,000 to 50,000. No steel piston will support as much as 50,000; carboloy, however, the recently developed substance for tools formed by cementing a fine powder of tungsten carbide with cobalt, fortunately proves to have a compressive strength high enough for the purpose.

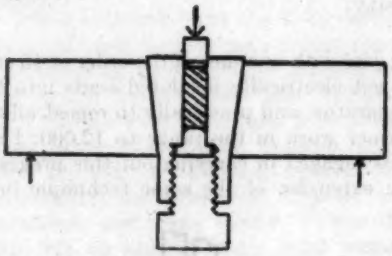

FIG. 2.—Illustrating the general principle of the method for giving external support to the pressure vessel in such a way that support increases automatically with the increase of internal pressure.

The next step in extension of range, from 50,000 to 100,000 kg/cm², demands still more effective support of the pressure vessel. This is done by immersing the entire pressure vessel in a fluid under pressures ranging up to 30,000 kg/cm². The pressure apparatus has to be made still smaller, the pistons are only 1.6 mm in diameter, and the capacity is only a few cubic millimeters. The pressure cylinder itself, as well as the pistons, is now made of carboloy with an external jacket of shrunk-on steel to give it greater strength. The piezometer is illustrated in Fig. 3. Even with this type of construction so great an extension of range as from 50,000 to 100,000 would not have been possible if it were not for a fortunate change in the properties of metals under pressure. At pressures of 25,000 kg/cm² ordinary grades of steel become capable of almost indefinite deformation without fracture, so greatly has their ductility been increased, as shown in Fig. 4. Even carboloy loses its normal brittleness and becomes capable of supporting higher tensile stresses without fracture than steel.

Up to the present, the compressibilities and polymorphic transitions of some 30 elements and simple compounds have been studied in the range to 100,000 kg/cm².

Much higher pressures than 100,000 can be reached in very small regions by constructing the apparatus entirely of carboloy, but up to the present no particularly important physical results have been attained in this range.

In addition to the problem of attaining the pressures, there is the problem of measuring them and measuring the effects which they produce. This demands in the first place the establishment of various fixed points. In the range up to 30,000 a sufficient number of such points has been established to permit measurements to an accuracy of about 0.1 percent. A transition of bismuth in the neighborhood of 25,000 gives one convenient such point. An essential part of the measuring technique is the utilization of the change of resistance of manganin under pressure, first suggested by Lisell at Uppsala. Above 30,000 the territory is not so well marked out; it is probable that the measurements to 100,000 have an accuracy of about 2 percent.

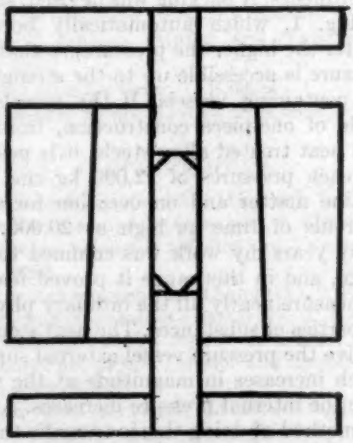

FIG. 3.—The miniature apparatus for reaching 100,000 kg/cm².

It is natural to think of volume compression as the simplest and most fundamental of all the effects of hydrostatic pressure, and for that reason it will be discussed first here. It is not, however, the simplest to measure experimentally, because the measurements immediately obtained are relative to the containing vessel, which is itself distorted.

Elaborate procedures may be necessary to eliminate the effect of such distortion.

The compression of gases is outside the range of this work; at pressures of 1,000 kg/cm² or more the densities of gases become of the same order of magnitude as those of their liquid phase, and there ceases to be any essential difference between gas and liquid. If the volume of any ordinary liquid is plotted as a function of pressure at constant temperature, a curve will be obtained which at low pressures has a high degree of curvature and a steep tangent, meaning a high compressibility, but as pressure increases the curvature rapidly becomes less and the curve flattens off. In Fig. 5 the volume of a typical liquid, ether, is shown as a function of pressure. For comparison, the curve of the most compressible solid, caesium, is also shown. Two different physical mechanisms are primarily responsible for the different behavior in the low and high pressure ranges. The low range of high compressibility is the range in which the chief effect of pressure is to push the molecules into closer contact, eliminating the free spaces between them. In this range individual substances may show large and characteristic individual differences. In the higher range the molecules have been pushed into effective contact, and the compressibility now arises from the decrease of volume of the molecules themselves. This effect persists with comparatively little decrease over a wide range of pressure. This effect is of course present also in the lower range of pressure, but there it is masked by the much larger effect arising from squeezing out the free spaces between the molecules. If one attempts to set up a formula for the effect of pressure on volume on the basis of measurements in the low range only, one will be likely to neglect too much the contribution from the compressibility of the molecules, with the result that the actual volumes at high pressures will be found to be materially smaller than the volumes which would be extrapolated from the low pressure formulas. This, as a matter of fact, has been a property of practically all the

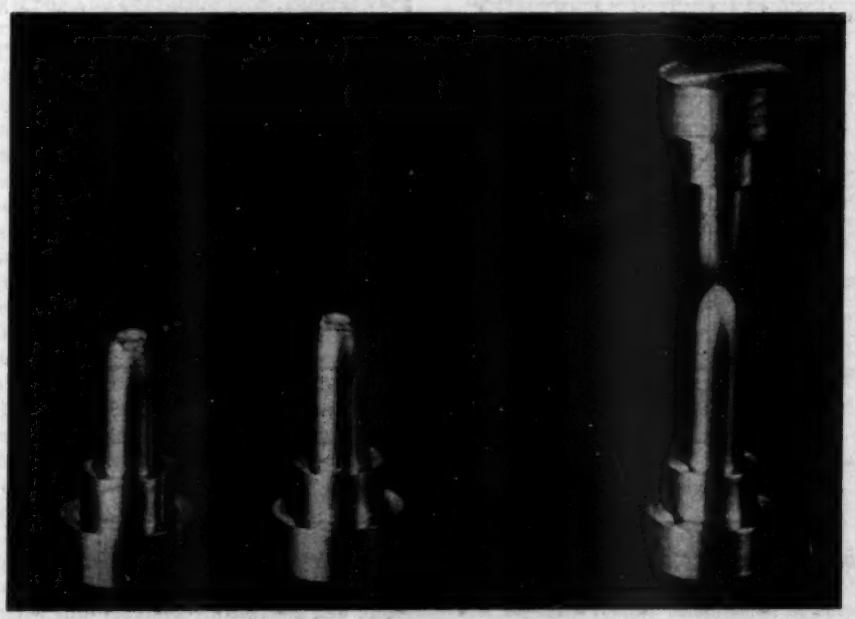

FIG. 4.—Illustrating the effect of pressure in increasing the ductility of steel. On the left, a piece of mild steel broken in tension at atmospheric pressure. On the right, the same steel pulled to a much greater reduction of area without fracture in a liquid at 25,000 kg/cm².

formulas that have been derived from low pressure data.

At high pressures, the volumes of ordinary organic liquids become surprisingly alike in spite of initial differences. To illustrate the rapid falling off of compressibility with pressure, the volume change in the first 5,000 kg/cm² is roughly the same on the average as the volume change between 5,000 and 50,000; the effect is accentuated by the fact that the volume decrement in the latter range often includes the volume discontinuity on freezing.

In the low pressure range, in which the molecules are being pushed into effective contact, one might expect effects depending on the shapes of the molecules, and that these effects would be highly specific with the liquid. This is the case. In the low pressure range a great variety of small-scale abnormalities are superposed on the larger scale uniformities, and these small-scale effects vary greatly from liquid to liquid. Thus there may be sub-ranges of an extent of a few thousand kg/cm² in which the compressibility increases with increasing pressure instead of decreasing as is normal, or the thermal expansion may also increase with increasing pressure instead of decreasing. Any satisfactory theory of liquids must ultimately give an account of these small-scale effects but for the present the large-scale effects must have first attention. When the theory of liquids does come to be written, the first step may well be to set up an idealized "perfect liquid" in analogy to the perfect gas which has played so important a role in the theory of gases. The experimental results at high pressures show sufficient uniformity in the behavior of all ordinary organic liquids to indicate that such an idealized perfect liquid is not too far from the actuality.

The compressibility of solids varies over a much wider range than does that of the ordinary liquids; caesium, for example, is 350 times more compressible than diamond. The highest compressibilities among solids, judging from indirect evidence, are probably to be found in solid hydrogen and helium. As in the case of liquids, the compressibility of solids normally drops off with increasing pressure. This would be expected in general because of the operation of a law of "di-

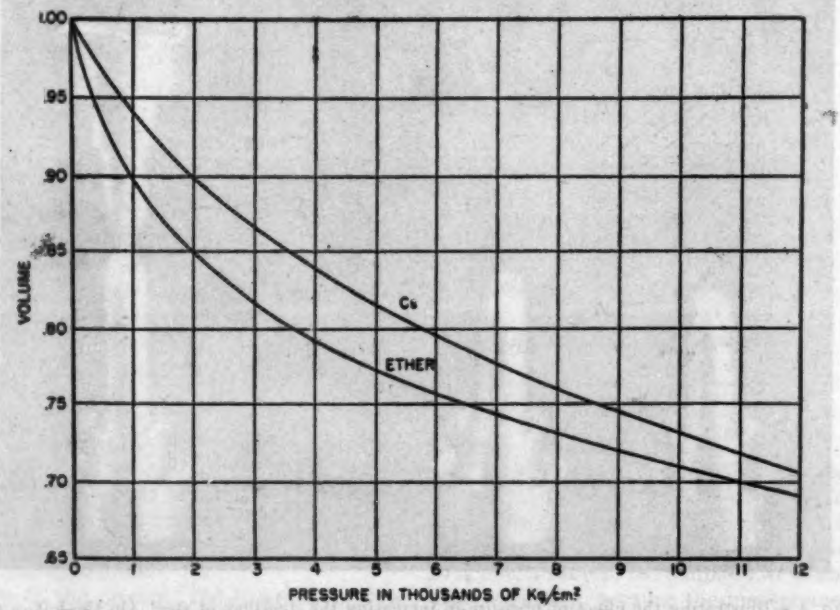

FIG. 5.—Volume as a function of pressure for a typical liquid, ether. The corresponding curve is also shown for caesium, the most compressible solid. The liquid is initially much more compressible than the solid, but at higher pressures is less compressible.

minishing returns," and is obviously necessary when pressure is raised indefinitely because if volume continued to decrease at its initial rate it would eventually become negative. For instance, the volume of caesium would become negative at a pressure of only 14,000 kg/cm² if it continued to decrease with pressure at the initial rate. In spite of the fact that the compressibility of solids on the average must decrease with increasing pressure, there is a very marked qualitative difference as compared with liquids. The initial phase of very rapid decrease is absent, and the decrease is spread more uniformly over the entire pressure range. The difference is to be accounted for by the lattice structure of solids; with increasing pressure the atoms retain their position in the lattice with the result that a smaller part of the free space between the atoms is available for occupancy as the centers of the atoms are forced closer together.

The volume decrements of a number of the more compressible solids are shown as a function of pressure up to 100,000 kg/cm² in Fig. 6. The curvature is in general very marked.

There is no thermodynamic necessity that the compressibility should decrease with increasing pressure, although this opinion has sometimes been expressed. Solid substances are known in which the compressibility may increase with increasing pressure over a comparatively wide range of pressure. The most striking example is quartz glass. The compressibility not only increases with pressure, but increases at an accelerating rate. This continues up to 35,000 kg/cm² and then abruptly stops. At this pressure there is a discontinuity in the derivative, a transition of the "second kind" in the nomenclature of Ehrenfest, and from here on compressibility decreases with rising pressure as is normal. The mechanism which is responsible for the low pressure effect abruptly ceases to act. Fig. 7 shows the relations.

So far we have been considering the effect of pressure on the volume of isotropic substances; this includes substances like glass and all cubic crystals. If the material crystallizes in some non-cubic system, the effects are more complicated. The compressibility is not the same in all directions, so that the shape of bodies composed of such crystals may change under pressure. The differences of compressibility in different directions may be large; thus zinc is eight times as compressible in the direction of the hexagonal axis as at right angles to it. Some difference in this direction might be expected, because the atomic spacing is greater along the axis than at right angles, but no simple consideration would lead to the expectation of differences as large as this. There is even one substance, tellurium, which has a negative compressibility along the axis. That is, when a single crystal of tellurium is subjected to hydrostatic pressure by a fluid in which it is completely immersed, it expands along the axis.

Considerable success has been achieved in calculating theoretically the effect of

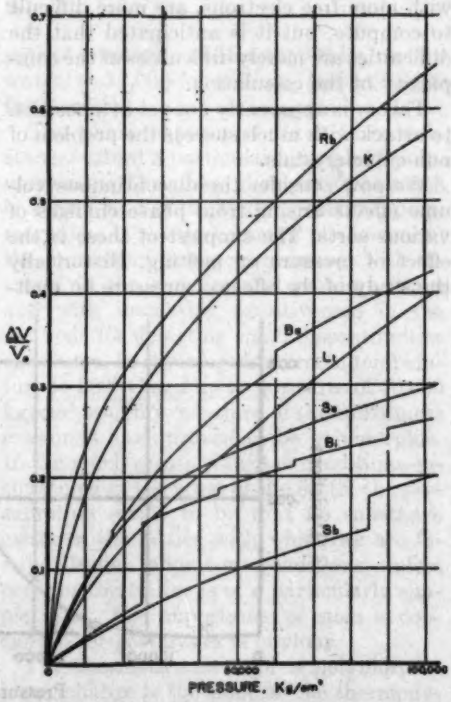

FIG. 6.—The volume compression of several elements up to 100,000 kg/cm². The breaks in some of the curves indicate polymorphic transitions.

pressure on the volume of simple solids. The first success was with simple ionic lattices of the type of NaCl by Max Born, who was able to get acceptable values for the lattice spacing and for the initial compressibility. He was not at first successful, however, in reproducing the change of compressibility with pressure, and even today complete success has not been attained in this regard. More complete results have recently been obtained for the alkali metals by applying the methods of wave mechanics. Bardeen has had surprising success in reproducing the entire volume curve over the experimental pressure range for the alkali metals. The calculations are particularly simple here because there is only one free electron per atom, and it turns out that the major part of the effect arises from the increase of kinetic energy of the free electrons arising from their decrease in effective wave length when the volume is decreased. Other metals, with more free electrons, are more difficult to compute, but it is anticipated that the difficulties are merely difficulties of the complexity of the calculation.

Theory is apparently not yet in a position to attack with much success the problem of non-cubic crystals.

We now consider the discontinuous volume effects arising from phase changes of various sorts. The simplest of these is the effect of pressure on melting. Historically the study of the effect of pressure on melting was approached with the anticipation that the effects would be found to be similar to the effect of pressure on vaporization, and in particular that there would be critical phenomena, so that above a certain pressure and temperature continuous passage would be possible between liquid and solid. It soon appeared, however, that the pressure scale of any such effects must be much more extensive than the scale of the critical effects between liquid and vapor, and that whereas pressures of a few hundred kg/cm² were adequate in the latter case, pressures of thousands of kg/cm² would be required to produce analogous effects for solid and liquid, if indeed they could be produced at all. With every extension of pressure range the probability of the existence of any such critical phenomena has become increasingly remote. Melting curves have now been followed up to 40,000 kg/cm²; a number of these are shown in Fig. 8. The melting curves of all substances have certain qualitative features in common, so that it is appropriate to speak of "the" melting curve just as one may speak of "the" vaporization curve. In other respects, however, the situation with regard to melting is qualitatively different from that with regard to vaporization. In particular, all melting curves, that is, the curve of melting temperature against pressure, are concave toward the pressure axis with a curvature becoming less at higher pressures,

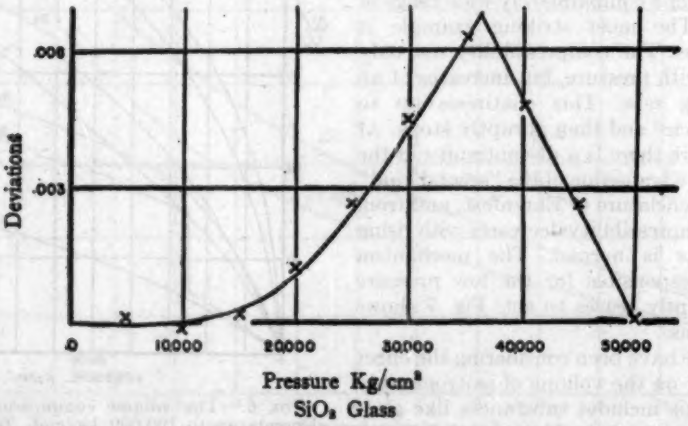

FIG. 7.—The deviations from linearity of the volume decrements of quartz glass for pressure increments of 5,000 kg/cm² plotted against pressure. The cusp in the curve marks the change from abnormal to normal behavior.

and the curve of difference of volume between liquid and solid as a function of pressure is convex toward the pressure axis with a curvature decreasing with increasing pressure. No critical point has ever been observed in the experimental range. If there were such a point outside the range, the latent heats and the volume difference between liquid and solid would have to vanish at a common pressure and temperature. Extrapolation of the curves for latent heat and volume difference indicates that neither of them will vanish at any finite pressure or temperature, to say nothing of both vanishing at the same pressure and temperature. The probability at present seems overwhelming that there can be no critical point between liquid and solid, at least for the type of substance investigated up to now, which includes organic substances of various types and a few metals. The same line of argument rules out the existence of other such features on the melting curve as a maximum temperature or an asymptotic temperature. In general, the melting curve rises to indefinitely high temperatures with indefinitely increasing pressure but at a diminishing rate, the curve becoming more nearly linear.

It is possible to show thermodynamically that if a substance expands when it melts, its melting temperature must rise with increasing pressure, and, conversely, it falls. There are only three substances which belong to the latter category in the ordinary range, water, bismuth, and gallium. Consistent with thermodynamics the melting curves of these three substances are found to fall. Furthermore, the curvature increases and the curves drop more and more rapidly as pressure increases. Such a state of affairs apparently cannot continue indefinitely. Nature extricates itself from the dilemma by the "liquidating" of such abnormal substances. Above a certain pressure the lattices in which these substances initially crystallize become unstable, and the lattice collapses into another lattice. The new lattice has a volume so much less than the former lattice that the solid phase is now more dense than the liquid, and from here on the melting curve rises as for other substances. The collapse of the lattice occurs at a pressure of about 2,000 kg/cm² for water, at 12,000 for gallium, and at 25,000 for bismuth.

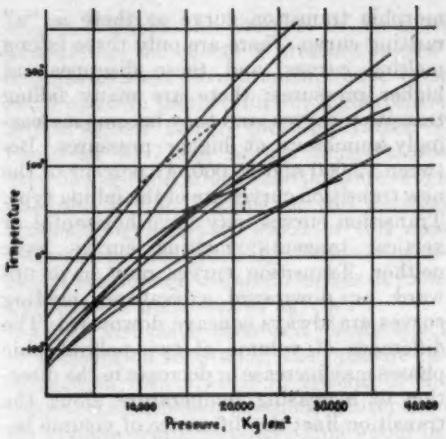

FIG. 8.—Melting temperature against pressure for a number of substances. At 15,000 kg/cm² the order of substances, reading from top down, is chloroform, chlorobenzene, chlorobenzene (second modification), water (ice VI), n-butyl alcohol, carbon bisulphide, methylene chloride, n-propyl bromide, ethyl bromide, and ethyl alcohol.

The phase changes of these three substances afford a particular example of polymorphism. The phase diagram of bismuth is shown in Fig. 9. Under pressure, polymorphism is a very common phenomenon; the number of instances increases with increase in the experimental pressure range and with increasing sensitiveness in the methods for detecting small discontinuities of volume. In the range from room temperature to 200° C and up to pressures of 50,000 kg/cm², roughly one-third of the substances examined have proved to be polymorphic. In the much greater range of conditions encountered in the crust of the earth, the presumption seems to be that no substance exists in the lattice with which we are familiar under laboratory conditions, unless perhaps the lattice is of a particularly simple type. The importance of such a conclusion for geophysics is obvious.

The thermodynamics of a polymorphic phase change is the same as the thermodynamics of melting, but beyond that there is little resemblance between the two phenomena; there is no such thing as "a" poly-

morphic transition curve as there is "a" melting curve. There are only three falling melting curves, and these disappear at higher pressures; there are many falling transition curves, and they become increasingly numerous at higher pressures. Between 12,000 and 50,000, 41 percent of the new transition curves are of the falling type. Transition curves may have horizontal or vertical tangents; melting curves have neither. Transition curves may have upward or downward curvature; melting curves are always concave downward. The difference of volume of two polymorphic phases may increase or decrease in the direction of increasing temperature along the transition line; the difference of volume between liquid and solid always decreases. The compressibility of the high pressure phase may be greater or less than that of the low pressure phase; the compressibility of the liquid is always greater than that of the solid. Substances are capable of existing in a number of polymorphic forms, and the complete mapping of the transition temperatures and pressures for all the forms may result in phase diagrams of great complication. Thus bismuth has six different phases; water, which has some striking analogies to bismuth, has seven phases. The most complicated phase diagram investigated to date is that of camphor, which has eleven phases.

There are only two generalizations with regard to polymorphic transitions that stand to date. The first is that critical points and continuous transitions between different polymorphic forms do not occur. If there were such points this would demand a continuous transition from one type of lattice to another, and this seems highly improbable, although perhaps not logically inconceivable. The second generalization is that transitions in the simple CsCl type of lattice in the direction of smaller volumes are not produced by pressure; this lattice seems to be of such a simplicity that it is not likely to be disturbed. This second generalization naturally rests on a much smaller number of examples than the first, and is correspondingly less secure.

We have so far been discussing transitions which are thermodynamically reversible; when pressure is released the origi-

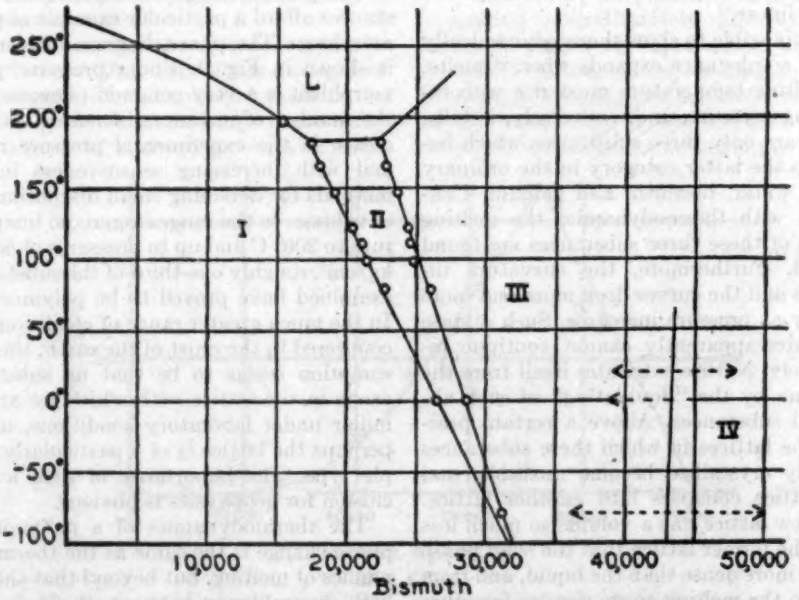

FIG. 9.—The phase diagram of bismuth. The arrows on the transition line III–IV indicate the pressure limits within which the transition runs with increasing or decreasing pressure.

nal form is resumed. In addition to these reversible transitions, the existence of irreversible transitions is to be recognized, that is, of changes effected by pressure which remain permanent when they have once taken place. Two well-marked examples of this have been found. The first was phosphorus. If ordinary yellow phosphorus is exposed to pressures above 12,000 kg/cm² at temperatures above 200° C, it is permanently changed into a black solid much like graphite in appearance and like it a conductor of electricity, although yellow phosphorus is a good insulator. This remained the only example for many years. Recently I have found that ordinary liquid CS_2 may similarly be changed permanently into a black solid at temperatures in the neighborhood of 200° C and by pressures of the order of 40,000 kg/cm². This black substance is definitely not a mixture of sulphur and carbon, which one might at first expect, but is apparently a unitary substance, truly a black solid form of carbon bisulphide. It has been suggested that the structure may be that of a single giant molecule like the known structure of SiO_2, which from the atomic point of view is very similar. It is fascinating to speculate that there may be many other common substances which may be pushed by sufficiently high pressures over a potential hill of some kind permanently into some hitherto unknown form. Until we have theoretical understanding of these two known permanent transitions, we can not help attaching a certain reasonableness to the assumption of the possible existence of other such substances. In fact, there is experimental evidence that many other such transformations may be effected. In experiments in which I combined high shearing stresses with high hydrostatic pressure I have observed some cases of irreversible transitions to forms already known, and have also observed a large number of color changes, which are the indication of some sort of permanent change. It was not possible to establish whether new substances were formed under these conditions because the quantities of material involved were too small to permit satisfactory analysis.

We pass now to other sorts of pressure effects. Perhaps the simplest of these to measure are the effects of pressure on electrical resistance. Measurements have been made at room temperature or higher up to 30,000 kg/cm² and at the temperature of liquid air to 7,000. At low temperatures there is a natural limit to the pressure range imposed by the freezing of the medium transmitting pressure, which in this case was gaseous nitrogen. Fig. 10 shows the effect of pressure on the alkali metals at room temperature up to 30,000 kg/cm².

In the first place, there is a specific effect of pressure on resistance; the pressure coefficient of resistance is in general of the order of magnitude of ten times greater than the volume compressibility. This would involve as a corollary that the effect of pressure on the resistance of a highly compressible metal is greater than on a metal of low compressibility. This is indeed true in general, but exceptions are common. The resistance of perhaps three-quarters of the metals decreases with increasing pressure; as is to be expected, the rate of decrease itself decreases with increasing pressure, that is, the curve of resistance against pressure is convex toward the pressure axis. On the other hand, there are several metals, of which lithium, strontium, and bismuth are examples, whose resistance increases under pressure. For these metals, surprisingly, there is a law of increasing returns, that is, the rate of increase of resistance itself increases with increasing pressure. This means that for these metals also the curve of resistance against pressure is concave upward. Finally, there are a few metals which combine both types of behavior, that is, the resistance initially decreases, then passes through a minimum, and then turns upward. Examples are caesium, rubidium, potassium, and barium. It would appear, therefore, that the upward curvature is common to all metals, and that all resistance curves may be regarded as pieces of one single curve, the only difference for different metals being that what might be called the intrinsic zero of pressure is differently situated with respect to atmospheric pressure for different metals.

Considerable success has been achieved by theoretical physicists in explaining theo-

retically the effect of pressure on resistance. As might be expected when effects departing so largely from linearity are concerned, we can recognize the presence of at least two different mechanisms working in opposite directions. There is in the first place an effect of pressure on what is the analogue of the electron free path in the old electron gas theory of metallic conduction. This is connected with the change of dimensions, and in general works in the direction of an increase of free path, that is, a decrease of resistance, with increasing pressure. In the second place, there is a rearrangement of the energy levels, and this may, when the energy bands are nearly completely occupied, work in the direction of a change in the effective number of free electrons. Deconding on the details of the atomic relations, this effect may be either an increase or a decrease. The calculations have been carried through approximately in a few simple cases. It turns out that the increase of resistance of lithium with pressure is due to the preponderating effect of a decrease in the effective number of free electrons.

The effect of pressure on the electrical resistance of single crystals is sometimes very complicated. If the crystal system is cubic, the material behaves electrically like an isotropic body, but if the system has lower symmetry, there may be differences in different directions. In antimony, for example, the sign of the pressure effect is different in different directions. There are directions in the crystal for which the resistance passes through a maximum with increasing pressure, whereas for other directions the resistance decreases with normal curvature.

The resistance of some semi-conductors may be decreased by such large amounts that they approach the absolute resistances characteristic of the metals. An early investigation in this field was made on

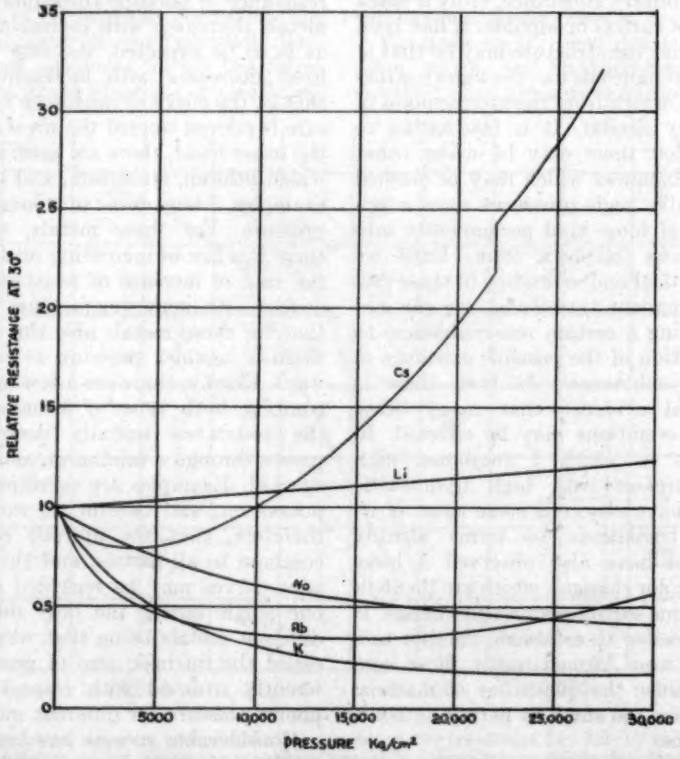

FIG. 10.—The relative resistances of the alkali metals up to 30,000 kg/cm². The break in the curve for caesium is due to a polymorphic transition. Potassium has a very flat minimum near 23,000.

selenium and silver sulphide by Montén in Uppsala. At higher pressures, tellurium approaches the properties of a metallic conductor under 30,000 kg/cm². Not only does the absolute value of the resistance drop to a characteristically low figure, but the temperature coefficient, which initially is negative, reverses sign under high pressure and becomes positive like that of the metals proper. Theory is as yet hardly in a position to explain these complicated effects, either in single crystals or in semi-conductors.

Closely related to the electrical conductivity of metals is their thermal conductivity; the relationship is expressed by the approximate equality of the Wiedemann-Franz ratio of electrical to thermal conductivity for all metals. Under pressure, thermal conductivity changes as well as electrical conductivity. It is much more difficult to measure than electrical conductivity, and satisfactory measurements have been made only for a few metals and those up to only 12,000 kg/cm². It appears that for these metals the Wiedemann-Franz ratio is approximately independent of pressure.

The effect of pressure on the thermal conductivity of liquids is much larger than on that of metals, and is much easier to measure. In general, the thermal conductivity increases for ordinary liquids under a pressure of 12,000 kg/cm² by a factor varying between 2 and 3. The effect on water is smaller; at 12,000 the increase for it is only 50 percent. There is a close connection between the effect of pressure on thermal conductivity of normal liquids and the effect of pressure on the velocity of sound in the liquid. That is, thermal conductivity in a liquid is primarily a mechanical affair; heat is transferred by microscopic mechanical waves travelling with the velocity determined in the conventional way by the compressibility. The small effect in water is associated with the small change in the compressibility of water brought about by pressure.

Another property of metals obviously related to electrical and thermal conductivity is the thermo-electric characteristics. These properties are also affected by pressure. In general, a metal under pressure behaves thermoelectrically differently from the same metal not under pressure, so that a thermo-

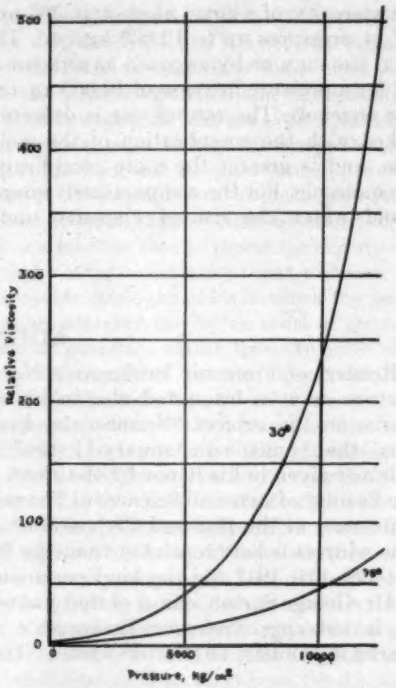

FIG. 11.—The effect of pressure on the viscosity of i-butyl alcohol.

couple may be made with one branch of any ordinary metal and the other branch of the same metal exposed to hydrostatic pressure. Under a pressure of 12,000 kg/cm² the thermoelectric power of such couples may be as large as that of ordinary couples composed of two entirely different metals. A number of such "pressure couples" have been investigated. The effects are complicated; there is not any universal rule with regard to the sign of the effect. There may be reversals of sign and large departures from linearity. No satisfactory theory of these effects has been formulated. At present one can only draw the conclusion that the interplay of several different mechanisms must be involved.

The largest of all the pressure effects studied to date is on the viscosity of liquids. In general, viscosity increases under pressure at a rate increasing rapidly with increasing pressure. The curve of viscosity against pressure usually rises exponentially with pressure and sometimes more rapidly than exponentially. In Fig. 11 is shown

the viscosity of i-butyl alcohol at 30° and 75° at pressures up to 12,000 kg/cm². The total rise may be by as much as a factor of 10^7 for a pressure increase of 10,000 kg/cm² (for eugenol). The rate of rise is definitely linked with the complication of the molecule, and is greater the more complicated the molecule. For the comparatively simple liquid water the rise of viscosity under 10,000 kg/cm² is by a factor of only 2 or 3 and for monatomic mercury by only 30 percent. For methyl alcohol the increase is by a factor of 10, for propyl alcohol by a factor of 100, and for amyl alcohol by a factor of 1,000. In the last few years the theoretical physicists have had considerable success in accounting for the effect of pressure on the viscosity of liquids.

EDITOR'S NOTE

Readers of Professor Bridgman's Nobel Lecture may be interested also in his remarks on the subject "Science and Freedom" that he made on January 11, 1947, at a dinner given in his honor by the Dean of the Faculty of Arts and Sciences of Harvard University at the Harvard Club of Boston. The address is here reprinted from the Isis 37: 128–131. 1947, by the kind permission of Dr. George Sarton, editor of that journal. In introducing Professor Bridgman's remarks in the Isis, Dr. Sarton wrote: "They are of great interest to historians of science because they reveal the afterthoughts which do not appear in [his] scientific papers, nor even in the philosophical ones, yet which are essential for the understanding of a man's personality. The document . . . is of great value for the 'new humanists,' who wish to understand not only the technical aspects, but also the human factors, without which there would be no science, or without which science would lose its meaning and its grace."

SCIENCE AND FREEDOM: REFLECTIONS OF A PHYSICIST

By PERCY W. BRIDGMAN

This will not attempt to reproduce exactly what I said at the dinner on January 11, 1947, but I shall avail myself of the suggestion of Dr. Sarton to make a partly imaginary speech, composed of parts of what I actually said, and of what, in the light of afterthought, I wish I had said. I shall not attempt to reproduce a number of the more or less personal and informal details, but shall confine myself to matters of more general interest.

Of all the conditions of my work which in retrospect appears most important, and of which at the time also I was keenly conscious, freedom of investigation is outstanding. There has never been any suggestion from any outside source as to the nature of my investigations. Even in the early days, when I sought and obtained the maximum relief from teaching and administrative duties for the ostensible purpose of more complete devotion to my research, no attempt was made by the University authorities to impose as a condition that I continue to devote myself to high pressure investigation or even to investigation itself. The apparent attitude of the authorities was that if you are going to gamble that you have found a good man, a gamble without strings attached is the most likely to succeed. Any consistency which my experimental program may have shown has been a consistency imposed entirely from within; this I believe to be the proper source of consistency. In spite of the fact that I have in the main followed one guiding experimental idea, I have nevertheless at all times felt free to pursue other lines of interest, whether experiment, or theory, or fundamental criticism.

Another outstanding characteristic of my work has been the smallness of its scale. Not only is the apparatus itself small, in fact becoming smaller the higher the pressure, because of inherent physical limitations on strength,

but I have never had more than two or three students at a time or a couple of assistants. The result has been that I have been able at all times to maintain the closest contact with the details of the work, and also have been able to conserve the requisite amount of leisure. Both of these features have been of the highest importance. In advancing into new territory, as in this high pressure work, the necessity is continuous for the development of new methods and new ideas. For me, at least, new ideas germinate only in an atmosphere of leisure. I have to immerse myself in a problem and then let it gestate in my brain, without the distraction of other interests, if I am to expect the solution to come sauntering into my mind when I wake up two or three mornings later. In this process manual cooperation plays a great part. Adjoining my laboratory is my machine shop; in fact, it is an integral part of the laboratory to which I can repair and stimulate inspiration by working out half-formed ideas with my own hands. Not only do I have enough leisure so that I can work in the shop with my own hands on occasion, but I am also able to carry through my own experiment, including making all the readings, myself. I find this necessary if I am to have confidence in the results of some method not hitherto tried. There are too many pitfalls of unanticipated sources of error, which often require ingenuity for their elimination, and which may take much time to discover if one is only watching from the side lines. I have been able to make it an invariable practice to stay with each new method long enough to get material for a complete paper, before turning the method over to an assistant for more or less routine application to a large number of substances. Not only this, but even when an assistant makes the experiment and the readings, I have always made the computations and written the paper myself. This gives me a confidence in the results not possible when working on a larger scale. Another great advantage of working on a small scale is that one gives no hostages to one's own past. If I wake up in the morning with a new idea, the utilization of which involves scrapping elaborate preparations already made, I am free to scrap what I have done and start off on the new and better line. This would not be possible without crippling loss of morale if one were working on a large scale with a complex organization under one.

Another characteristic of the field in which I have been working is that it is not a particularly popular field, so that there have been comparatively few workers in it and correspondingly little competition. This has both advantages and disadvantages. It is an advantage that one can do his work with no sense of hurry, so that there is little temptation to make premature announcements, and should questions arise one can take the time to repeat the experiment or make other modifications that will clear up the matter. Also, the order in which the problems are attacked can be the order of greatest scientific economy, rather than the order of a competitive politics. On the other hand, the principal disadvantage, obvious enough to everyone, is that the investigator loses the stimulation of conversation with his colleagues on mutual problems. Just how important this stimulus is will depend in considerable measure on the individual investigator; some may find it well nigh indispensable, whereas others may be much less dependent on it. I myself have been able to get along in considerable measure without it. Even at scientific meetings, which every physicist seems to have to attend at intervals for rehabilitation of his inner man, the stimulus which I have received has not been detailed and specific, but rather general, in suggestions of trends and areas of coming interest. It has, I think, been a happy circumstance that my field, although obviously narrow in the sense that pressure is a highly specialized physical parameter, nevertheless from another point of view has been exceedingly broad. For the general problem has been no less than to determine the effect of pressure on all physical properties, and it therefore covers the entire reach of physical phenomena with the exception of such things as vacuum tube phenomena.

Mention of the stimulus of conversation with one's colleagues naturally prompts one to consider the increasing trend during the last few years to large-scale cooperative enterprises among physicists. The reasons for this are obvious in the enormously increasing size and expense of the apparatus necessary for modern physical research, such as the cyclotrons and the piles of nuclear physics. Although we may recognize that such instruments are necessary, we may nevertheless deplore some of the consequences. Up to now ideas have been in such a rapid state of flux that the instrument itself has been continually evolving, with the result

that most physicists in this field have been spending an increasingly large fraction of their time on the purely engineering job of the design and construction of new and better instruments and correspondingly an increasingly small proportion of time on the calculation of results and rumination on their significance. The competition in this field is intense; rivalry between different groups at different universities can offer little opportunity for leisure or the scholarly digestion of results before publication. Within the last year there has been one glaring example of hasty publication of a spectacular result of such presumptive importance as to start a rush of other investigators into the field, only later to be withdrawn as erroneous because of inadequate consideration of factors which obviously were crying for evaluation in the beginning. Not only is there haste because of competition, but there is haste because of financial considerations. The apparatus is so expensive that consideration of the overhead demands that the apparatus be kept in operation for twenty-four hours a day, and this is not conducive to a feeling of leisure. Each of the teams which is the slave of one of these instruments has to be driven by some one at the head who has the ideas. There is danger here that all the rest of the team will pick the brains of one man, with an ultimate decrease in the number of physicists in the community capable of independent and critical thought. Still worse, the physicist who should be directing his team by his creative ideas is likely to be so swamped by the administrative details of the large enterprise under him that he is overwhelmed and his purely scientific activity destroyed. This is well known to have happened, at least temporarily, in the case of one of the new mammoth calculating machines, machines whose ostensible purpose is to free the scientist from drudgery and make possible the creative use of his time. Doubtless some physicists have the natural knack of being able to work together harmoniously and perhaps even efficiently in teams, and perhaps others can acquire it, but I believe there are many who are permanently unfitted for effective cooperation in this way, and it will be a major loss if they are not able to find a niche in which they may function.

During the war practically all the physicists in this country were diverted to war work of one sort or another, and a large part of them were engaged in large-scale enterprises which involved team work developed to its maximum efficiency, with the consequent and necessary submergence of the individual. The older men, who had previously worked on their own problems in their own laboratories, put up with this as a patriotic necessity, to be tolerated only while they must, and to be escaped from as soon as decent. But the younger men, who had been drawn into the maelstrom before starting work for their Ph.D. degree, had never experienced independent work and did not know what it is like. Some of these younger men will continue in government work; others who return to academic circles will there join in the teams serving the mammoth instruments. The result is that a generation of physicists is growing up who have never exercised any particular degree of individual initiative, who have had no opportunity to experience its satisfactions or its possibilities, and who regard cooperative work in large teams as the normal thing. It is a natural corollary for them to feel that the objectives of these large teams must be something of large social significance. The temper of the rising generation is recognizably different from that of the older. I may mention one example with which I have had personal acquaintance. The Association of Cambridge Scientists was one of many similar associations formed soon after the dropping of the atomic bomb on Hiroshima to consider all the implications of the situation thus created. In the early days of the Association the May-Johnson bill was a matter of much concern. With regard to this there was in the ranks of the Association a cleavage of attitude almost exclusively along lines of age. The older men were troubled and concerned by the threats to scientific freedom contained in the bill, whereas the younger men were not at all concerned about this, but took the opposite view that it was on the whole a rather base and self-indulgent thing for the individual not to be willing to sacrifice his scientific freedom on the altar of the good of society. The young men, never having experienced scientific freedom, did and could not see that the question of self-indulgence does not enter at all into the situation, but the existence of science itself, which I think all conceded to be a social good, is impossible without scientific freedom.

The increasing amount of administrative work falling on some of the scientists compos-

ing the large teams has a parallel in the ever increasing amount of routine administrative work expected from the members of a University faculty. As I look back on the forty years of my work there can be no question but that the fraction of the time of the average faculty member spent in routine of administrative or other sorts has increased unconscionably. There seems to be a natural law operating here; the larger an institution becomes, the more cumbersome and less efficient it becomes. One might think that when the institution becomes ten times as large it would have ten times as much business and ten times as many people to do it, so that each individual would need to give only the same amount of time. But it does not work this way; it is more like the development of a telephone exchange, which when it increases by a factor of n has to provide for the handling of factorial n as many combinations. Each new functionary in a University has to justify himself, which he does by exacting attention from every member of the faculty. When, for example, the office of archivist is created, *every* member of the faculty is asked to provide material for the archives. Ten times as many officials tend to demand ten times as much attention from *each* member of the faculty. In a recent number of the Scientific Monthly there was an amusing and satirical article depicting the eventual extinction of the human race by suffocation in its own intellectual effluvia. It is well known that every large library tends to increase in size geometrically with the simple arithmetical passage of time. Why this should have to be true does not seem to have been explained, but it is an undoubted description of the observed behavior of the human animal. Unless some way can be discovered of breaking the cycle, the logical final result is catastrophic. In the past the cycle has been broken by wars and the collapse of civilizations. In the hoped-for brighter future in which war has been eliminated, some specific means will have to be devised to cope with the situation. The satirical article portrayed the consequences of the inability of the human race to devise an adequate means. It is no less a problem to devise a means by which the time of the members of university faculties may be saved for creative effort. Otherwise creative science will be driven to other asylums, if indeed it is not destroyed.

As I look to the future I am therefore troubled by two misgivings: that there will be less and less place for the small individual experimenter, and that the time of all of us will be increasingly commandeered by administrative mechanical details. In view of these misgivings I cannot help wondering as I look back on the past whether, if I were to start over again now, I would be able to do again what I have done.

CHEMISTRY.—*A method for the determination of certain metals present in minor concentration in various substances.*[1]

N. HOWELL FURMAN, C. E. BRICKER, and BRUCE MCDUFFIE, Princeton University. (Communicated by JAMES I. HOFFMAN.)

This paper presents an account of a systematic scheme for the determination of certain metals in a variety of substances. The scheme at first was directed toward the estimation of minor amounts of a few other metals that were found to occur in uranium or its compounds and salts. The method was gradually modified and extended in scope from 1942 to 1945 with the aid of G. P. Haight, Jr., J. A. Nyitrai, and others. The proved applications of the process, in addition to those already mentioned, include the estimation of minor amounts of various metals in the salts, alloys, or nearly pure metallic specimens of Ba, Be, Ca, Mg, and Na. From the experience thus far obtained it appears probable that the method could be applied to the testing of many other pure metals, their alloys, or compounds. The method is also applicable to the collection of the traces of metals that may occur in organic compounds or in

[1] Lecture delivered March 13, 1947, on the occasion of the award of the Hillebrand Prize in Chemistry by the Chemical Society of Washington to Dr. James I. Hoffman in recognition of his contributions on the extraction of alumina from clay and the purification of uranium for atomic energy. Received December 31, 1947.

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materials of biological and pharmaceutical interest.

The original problem had to do with the detection or the determination of certain metals of the hydrogen sulphide group, notably copper, cadmium, lead, and molybdenum, or the detection of copper, cadmium, iron, etc., in lead and its salts, or in bismuth and its compounds. It was therefore natural to explore the possibilities of mercury cathode electrolysis as a preliminary to polarography and colorimetry. The pioneer work of E. F. Smith on mercury cathode separations was at once utilized (1942) in connection with the estimation of minor amounts of cadmium in lead or bismuth or in lead compounds.

USE OF A SMALL MERCURY CATHODE TO COLLECT SMALL AMOUNTS OF METALS

The majority of the procedures that were later developed in detail centered around the use of a small mercury cathode as a collector for minor amounts of metals which were electrolyzed into the cathode under the conditions chosen. The mercury cathode was then drained into a weighed silica combustion boat without interrupting the current, and after removal of the mercury by distillation in a current of nitrogen the residues were weighed and dissolved and the conditions were adjusted for the application of polarography. After the polarographic estimations the residual solution was further utilized for certain spectrophotometric determinations. The solution, from which the electrodeposited metals had been removed by electrolysis, was examined systematically by extractions and colorimetric procedures for minor amounts of other metals, e.g. Mo, Fe, Ti, and V (*1*).

This method of concentration has very decided advantages prior to polarography because the supporting electrolyte can be controlled very simply for the estimation of minor amounts of metals recovered from a great variety of samples. The method has been found useful for the concentration of materials prior to spectrophotometric or spectrographic estimations. For routine application to a given material the weight of the residue from the mercury distillation gives an idea of the gross contamination of the material by the electrolyzable metals. Chance contamination of some part of a sample can be detected by virtue of the fact that a very large sample may be examined.

The general facts of electrolysis into a mercury cathode have been summarized as follows (*2*): The following metals singly or in association are quantitatively deposited in a mercury cathode: Cu, Ag, Au, Zn, Cd, Hg, Ga, In, Tl, Ge, Sn, Bi, Po, Cr, Mo, Re, Fe, Co, Ni, Rh, Pd, Ir, Pt. Further Pb, As, Se, Te, and Os are quantitatively separated from the solution, but are not necessarily deposited in the mercury. Mn, Ru, and Sb are partially separated from the solution.

The foregoing general facts had not been studied exhaustively in the minor concentration ranges in which we were interested, nor had the recovery of various metals by electrolysis into mercury and distillation of the latter been studied, although the recovery of gold after amalgamation is a well-known process.

Oxidation-reduction buffers.—In the electrolysis of specimens of which the major constituents may form oxidation-reduction systems such as the $U^{IV}-U^{III}$, $Ti^{IV}-Ti^{III}$, $V^{III}-V^{II}$, etc., the list of metals that are completely deposited in the mercury is curtailed because the cathode potential is not depressed far enough to reach the level necessary to deposit some of the metals. For example, from rather concentrated solutions of uranium sulphate no Mo, Cr, and Mn are deposited under conventional conditions of electrolysis. A further point that we have noted is that the level which the cathode reaches is affected by the deposition of traces of platinum, iron, copper, etc., on the mercury. These and other metals tend to lower the overvoltage of hydrogen deposition and to make the removal of certain metals less complete. Iron under some conditions is completely removed from a solution containing uranium but from concentrated solutions the removal is uncertain and it is necessary to test for iron both in the mercury deposit and in the aqueous solution after electrolysis.

The details of electrolysis, distillation, and colorimetry can best be described in the

following outline of the experimental development:

EXPERIMENTS AND PROCEDURES

The scale of operation was set up primarily for the analysis of micro-amounts of metals. The apparatus was so chosen that distillation residues in the range from 10 micrograms up to 5 mg of material could be handled. The sample size is adjusted so that the material electrolyzed and left after distillation will be in this range. This scale of operation is well suited to polarography. In general residues between a few tenths of a mg and 1.5 mg were handled so that the process is a true microprocedure from this point.

Apparatus and materials.—Silica dishes of 250 ml capacity or smaller were used in the preparation of solutions except for fluorides which were treated in platinum dishes.

The reagents used to dissolve the samples were at first redistilled from a silica still for acids or from Pyrex for distilled water. Redistilled mercury was used. Later it was found feasible to use analytical reagent acids and to run frequent reagent blanks through the whole process.

Electrolysis cells of special design as shown in Fig. 1 were used. It is important to have the wire leading to the cathode terminate as near the stop-cock as possible. Anodes of platinum alloyed with 10 percent of iridium are satisfactory. The mercury cathode is drained into a silica combustion boat 14 by 75 mm and 10 mm deep, with handle. Silica beakers of 150 ml capacity are used for dissolving the deposit.

A 12-inch split tube furnace of conventional design is used for the distillation. The nitrogen that is used to sweep out the mercury is not freed from air.

A recording polarograph, preferably of the Heyrovsky type is desirable. The instrument that was used in the development of the method has been described in the literature (*3*).

DEVELOPMENT OF PROCEDURES

The initial experiments were made by electrolyzing exhaustively a solution containing a large amount of the substance to be tested. The first mercury cathode was drained out and washed out with a little mercury. Then with a fresh mercury cathode a known addition of any metal to be tested was made, and the electrolysis was repeated and the mercury was drained out, distilled, and the residue tested. Since cadmium did not occur in the reagents, as proved by frequent blank tests, the extent of recovery of varying amounts of cadmium may be used as an illustration of the effectiveness of the method, Table 1.

TABLE 1.—TYPICAL RECOVERIES BY THE PROCEDURE

Cadmium added	Cadmium recovered	Percent recovered
mg	*mg*	
0.010	0.0095–0.010	95–100*
0.100	0.095 –0.100	95–100*
0.50	0.45 –0.50	90–100*
1.00	0.935	93.5
2.00	1.94	97
2.50	2.56	102
3.00	2.94	98
4.00	3.89	97
5.00	4.79	96

* Where a range is given several individual determinations were made.

A number of similar experiments were made with small amounts of various sub-

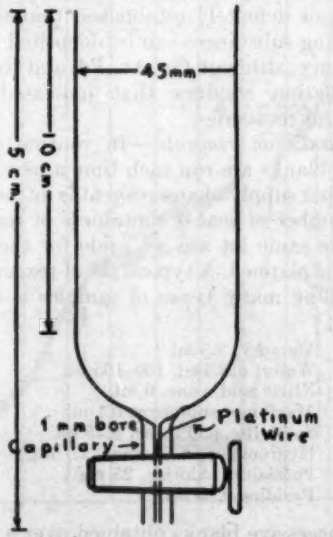

FIG. 1.—Cell for electrolysis. The cell is provided with a lip not shown. The anode is inserted over the lip and a cover glass is used.

stances added to uranyl solutions that had been purified by electrolytic or other methods. The results are corrected for blank values, and typical data are given in Table 2.

TABLE 2.—RECOVERIES OF VARIOUS ELEMENTS BY THE PROCEDURE

Element	Amount added	Percent recovered	Method of analysis
	mg.		
Co	0.05	95–100*	Colorimetric
	0.10	95–100*	"
	5.00	97.5	"
Cu	0.05	95–100*	Polarographic
	5.00	103	"
Pb	0.02	about 100*	"
Ni	0.02	95–100*	"
	0.10	95	"
	5.00	98	"
Zn	0.05	95–100*	"
	1.00	98–100*	"
Mo	0.20	None deposited, owing to oxidation-reduction buffering action.	
	1.00		
Cr	1.00	Doubtful. Probably none deposited.	
Mn	1.00	0–2	Colorimetric. In general no Mn is electrolyzed into the mercury.

* Several individual determinations were made.

A superficial investigation was made of the behavior of Bi, In, Tl, Ir, Ru, Ga, Au, Pd, Re, Se, and Te. The first three are quantitatively taken into the mercury. It was not definitely established that the remaining substances can be deposited in the mercury, although Ga, Au, Pd, and Re gave distillation residues that indicated substantial recoveries.

Blanks on reagents.—In routine operation, blanks are run each time a new bottle or other supply of any reagent is introduced. A number of sealed containers of reagents of the same lot are set aside for the work that is planned. A typical set of reagents for handling many types of samples is as follows:

Mercury, 2.5 ml.
Water, distilled, 160–165 ml.
Nitric acid, conc. 6 ml.
Maximum supressor, 0.1 ml.
Sulphuric acid, conc. 5.35 ml.
Hydrochloric acid, conc. 2.1 ml.
Potassium chloride, 25 mg.
Pyridine 0.15 ml.

Successive blanks obtained over a period of several weeks had the following range, in milligrams, Cu, 0.011 to 0.026; Fe, 0.023 to 0.039; Ni, 0.001 to 0.002; and Pb, 0.002 to 0.004.

Cadmium, cobalt, and zinc were not encountered in these reagents. Fluctuations in copper blanks were in one instance traced to a copper pin in an atomizer bulb that was used with a stock bottle of nitric acid. A series of erratic results for cadmium was due to cadmium contained in methanol that was used to wash metallic specimens that were greasy. The cadmium content of the methanol was 2 parts per million. It proved to be unwise to use the polarographic cells and the silica beakers for experiments with major amounts of any of the metals that were being estimated. The iron blank includes additional iron introduced by a succession of reagents that were used in connection with the recovery of iron from the solution that had been electrolyzed.

Calibrations.—Although it was possible to control the composition of the solution that was subjected to polarographic analysis rather rigorously, it was considered desirable to calibrate with mixtures of elements in the normal ranges that were encountered in applying the method. Certain calibrations were made with materials put through the complete process and with proper blank deductions. Other calibrations were made with mixtures of elements taken from standard solutions of their chlorides or nitrates. The solutions were handled in exactly the same fashion as the residues from the distillation of mercury. Perhaps the best evidence that the calibrations were consistent is to be found in the data of Tables 1 and 2. Some of the determinations there reported were on single substances and others were for mixtures of Cd, Cu, Co, Ni, Zn, and Fe in varying ratios.

Reproducibility of the procedure.—A few typical results on the recovery of minor amounts of elements from solutions are shown in Table 3.

Approximately the same degree of reproducibility was obtained in check determinations on numerous samples of various types. A typical example of the polarographic findings is shown in Fig. 2, which presents the polarograms taken from solutions of two equal samples of a slightly alloyed light metal.

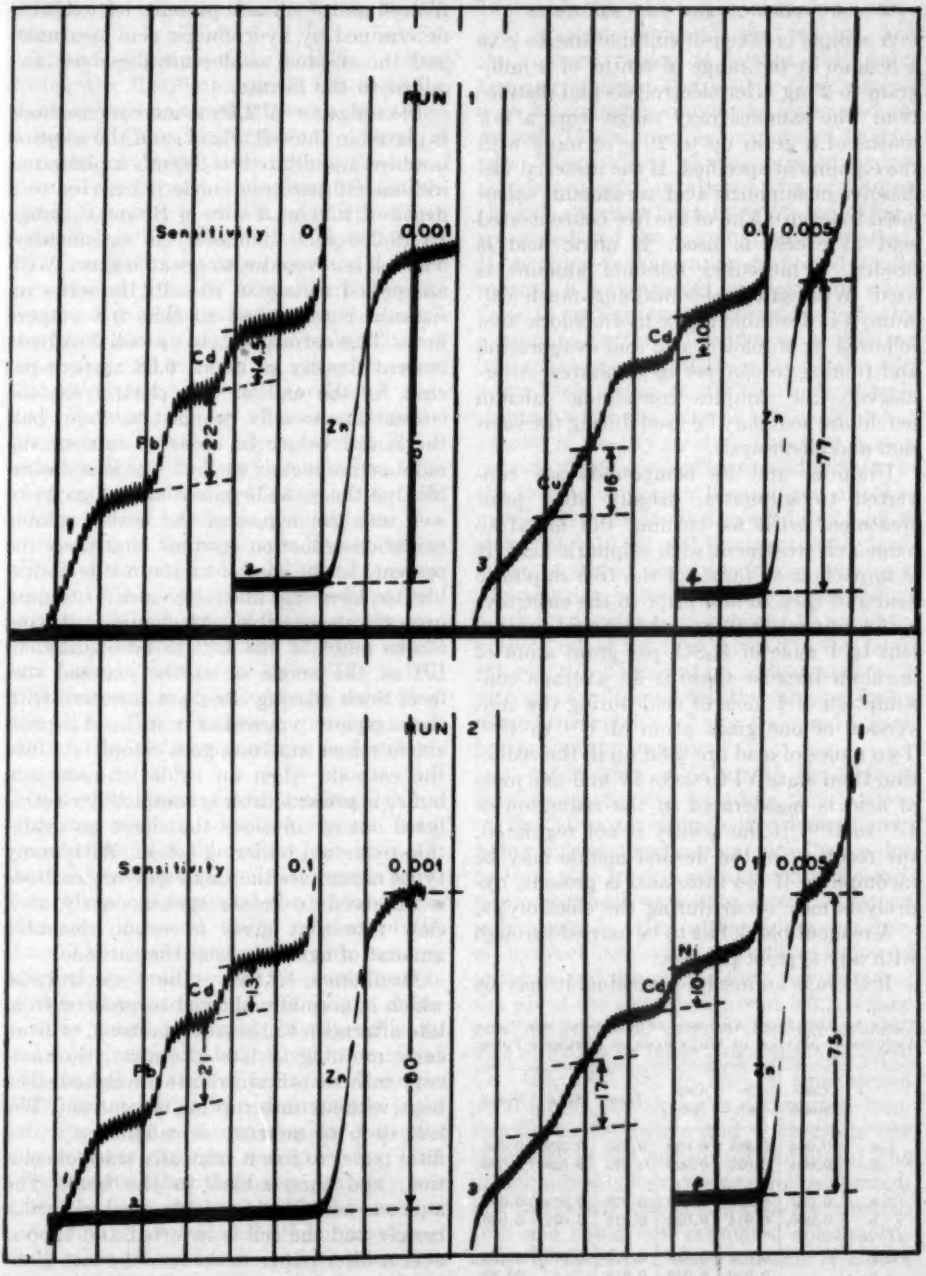

FIG. 2.—Duplicate analyses. Curves 1 and 2 are taken before adding pyridine; curves 3 and 4 after the addition of pyridine. The zinc wave in curve 4 is used for the qualitative estimation of this metal.

OUTLINE OF THE PROCEDURE

A sample is taken of suitable size to give a residue in the range of tenths of a milligram to 2 mg after electrolysis and distillation. The samples may range from a few tenths of a gram up to 20 g or more with the equipment specified. If the material will dissolve in sulphuric acid, an amount calculated to leave 0.5 ml of the free concentrated acid in excess is used. If nitric acid is needed, a measured minimal amount is used. With samples containing much calcium, it is desirable to use hydrochloric acid followed by sulphuric acid and evaporation and fuming to convert to sulphates. Alternatively for samples containing calcium perchloric acid may be used during the solution and electrolysis.

Uranium and its compounds are converted to sulphates, usually after prior treatment such as burning the metal to oxide and treatment with sulphuric acid. It is important to fume off the free sulphuric acid and then to add prior to the electrolysis an amount of free sulphuric acid equivalent to 1 mole of H_2SO_4 per gram atom of uranium because there is an average consumption of 1 mole of acid during the conversion of one gram atom of U^{VI} to U^{III}. Two moles of acid are used up in the reduction from state VI to state IV and one mole of acid is regenerated in the reduction of U^{IV} to U^{III}. If the acidity is not regulated, the recovery of the desired metals may be incomplete. If too little acid is present, hydrolysis may occur during the electrolysis.

A reagent blank has to be carried through with any type of process.

If there is an insoluble residue, it may be filtered and if silica is present, its weight is determined by hydrofluoric acid treatment and the residual oxides are dissolved and added to the filtrate.

Electrolysis.—A 2.5 ml mercury cathode is placed in the cell, Fig. 1, and the solution is added and diluted to 100 ml. A platinum-iridium (10 percent) anode is inserted to a depth of 1.5 cm. A wire of B. and S. gauge 15 (0.058 inch diameter) is satisfactory. The cell is covered with a watch glass. With an applied voltage of 10 volts the series resistance is regulated so that 0.8 ampere flows. This corresponds to an initial cathode current density of about 0.08 ampere per cm^2. At the end of the electrolysis the current has usually dropped to about half the initial value. In order to remove the more active metals such as zinc it is desirable that the cathode potential shall go down well into the region of the lowest soluble oxidation-reduction system that may be present. In the case of uranium it is desirable to have as much trivalent uranium present as possible. Mechanical stirring causes much of the U^{III} to be oxidized to U^{IV} at the anode or at the exposed surface. Such stirring does not interfere with the complete removal of iron. Lead if present in minor amounts goes completely into the cathode when an oxidation-reduction buffer is present. Iron is completely electrolyzed out of solutions that have no oxidation-reduction buffering action. With many types of samples the small mercury cathode is observed to rotate spontaneously at a slow rate that gives a certain desirable amount of agitation near the cathode.

Distillation.—After the electrolysis, which is normally allowed to proceed from late afternoon to the next morning, or from early morning to late afternoon, the mercury cathode is drained into a weighed silica boat, without interrupting the current. The last drop of mercury is caught on a dry filter paper to free it from any trace of solution, and then added to the boat. The aqueous solution is quickly washed into a beaker and the cell is inverted and tapped over a filter paper to recover the last globules of mercury which are blotted dry and added to the boat. If there is as much as a few tenths of a milligram of other metals

TABLE 3.—DUPLICATE ANALYSES OF SOLUTIONS FOR SMALL AMOUNTS OF METALS, IN MILLIGRAMS OF ELEMENTS FOUND

	Cadmium	Cobalt	Copper	Iron	Lead	Nickel
1, a.	0.004	0.023	0.029	0.367	0.029	0.005
b.	0.004	0.025	0.026	0.373	0.029	0.005
2, a.	0.001	0.025	0.026	0.620	0.012	0.006
b.	0.000,	0.014	0.022	0.615	0.012	0.006
3, a.	—	0.018	0.043	0.923	0.009	00.33
b.	—	0.020	0.038	0.918	—	00.30
4, a.	—	0.022	0.039	0.888	0.016	0.015
b.	—	0.023	0.058	0.863	0.010	0.011

present, the mercury has a visible surface scum.

The temperature of the boat is observed during the distillation with the aid of a thermometer inserted through the inlet stopper of the tube furnace. A current of nitrogen, not freed from oxygen, is passed through the furnace during the distillation, and the mercury is condensed in a beaker of water into which the outlet tube dips. As many as three boats at a time are handled in a 12-inch furnace. After distillation the temperature is lowered and when the boat is nearly at room temperature a cylinder of clean paper is inserted in order to avoid contact of the boat with condensed mercury droplets. There is a characteristic change from a golden brown color to bluish with amalgams rich in cadmium and the temperature is lowered as soon as this change becomes evident. If little or no zinc is present and the residue is largely iron it will be distributed in small specks on the bottom of the boat. Zinc and indium form amalgams which are decomposed only at a much higher temperature. The zinc amalgam forms a continuous layer. The weight of the residue is of little significance when zinc is a major component of the residue. Indium was only encountered in synthetic samples.

In residues that contain primarily iron plus very minor amounts of copper, lead, etc., the weight of the residue less the Fe_2O_3, that is equivalent to the iron, agrees fairly closely with the sum of the metals other than iron in about 65–75 percent of the cases. The weight is therefore only a rough index of over-all content of electrolyzable metals. The average ratio of weight of deposit to weight recovered polarographically and colorimetrically in the residue is about 1.88 for a given class of material. The ratio $Fe_2O_3/2Fe$ is 1.43. The discrepancy is in part due to the presence of minor amounts of mercury or platinum and to the fact that the elements other than iron probably are converted more or less completely to oxides.

Solution of the deposit. Polarography.— The boat is placed handle end up in a silica beaker of 150 ml capacity, and the residue is treated with 2 ml of concentrated hydrochloric acid and 1 ml of concentrated nitric acid. The acids are caused to come into contact with all the residue and the covered beaker is heated until solution is complete. The boat is then washed with a minimum amount of water and removed. The solution is evaporated to dryness. Then 0.5 ml of concentrated hydrochloric acid and an aliquot of a potassium chloride solution containing 25 mg of KCl are added and the evaporation is repeated. If mercury is known or suspected to be present, it is volatilized by heating on a hot plate at medium heat. The residue is finally evaporated after the addition of another 0.5 ml of concentrated hydrochloric acid and a little water, at 100°C. The heating is stopped while the odor of HCl is faint but present in the dry residue. This step is very important because sufficient acid remains in the residue to prevent loss of iron or other metals. The residue is dissolved in 2.9 ml of water, and 0.1 ml of 0.1 percent methyl cellulose is added as a maximum supressor. The solution is made homogeneous and as much as possible is transferred to a polarographic cell of the type devised in this laboratory (*10*). The solution is deaerated with nitrogen for 10 minutes, the nitrogen being passed through a purifying train and a wash bottle containing water.

A polarogram is taken at the highest feasible sensitivity, recording that portion of the current voltage curve immediately following the spontaneous initial wave due to iron, etc. In this medium only the cadmium and lead waves are useful. A second polarogram is taken after adding one drop of hydrochloric acid and three drops of pyridine and deaerating for a few minutes; the *p*H of the solution is about 5.2. Lingane and Kerlinger (*4*) proved that the precipitate of hydrated ferric oxide does not carry Cd, Cu, Co, Ni, or Zn. In this second polarogram the copper is determined from the Cu^{I} to Cu^{0} wave and a check is obtained as to the amount of cadmium. The nickel and cobalt waves are well separated, but the cobalt and zinc waves are merged. Iron and cobalt are estimated colorimetrically. If there is a large amount of zinc a third partial polarogram at lower sensitivity has to be taken to get the sum of the zinc and cobalt.

Platinum, if present in the residue from the mercury distillation, is sometimes revealed in the polarogram by a spontaneous rise at the start and an anomalous dip or decrease in current after the lead wave. The dip usually begins to be evident at −0.9 volt applied and reaches a minimum at −1.10 volt applied. The addition of a drop or two of hydrochloric acid eliminates this dip but causes a catalytic hydrogen wave to start at −0.8 volt applied. Platinum may make it difficult or impossible to determine the amount of zinc from the polarogram taken after adding pyridine. The terminal wave is shifted from −1.48 volts to −1.28 volts by 0.01 mg of Pt in 3 ml. With 10 times as much platinum the terminal wave begins at −1.13 volts.

Under the conditions chosen 10 micrograms per 3 ml of any of the common metals Cu, Cd, Pb, Co, Ni, or Zn cause a wave of the order of 1 cm. Under the most favorable conditions 1 microgram of a metal may be detected, provided the metal does not occur in the reagents. If iron is the dominant component of the solution the sensitivity of the detection of lead may be greatly diminished because lead can be detected only in the most acid medium where the sensitivity that may be used is governed by the height of the initial iron wave.

Other determinations.—Systematic procedures have been adapted from colorimetric determinations in the literature for the estimation of iron and cobalt in the solution that has been polarographed. The solution after electrolysis and separation of the electrolyzable metals may be tested systematically for such elements as molybdenum by thiocyanate extraction, after which iron, titanium, and vanadium may be extracted as cupferrates and determined by separate colorimetric tests.

SUMMARY

The possibility of using a small mercury cathode as a collector for minor amounts of electrolyzable metals has been explored and the procedure has been tested for a variety of applications.

A novel combination of techniques based on the distillation of the mercury from the cathode and the polarographic and colorimetric examination of the residue has been devised and studied extensively in a rather limited range of applications. The procedure appears to be capable of many further applications to a great variety of organic or inorganic substances.

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ETHNOLOGY.—*Self-torture in the Blood Indian sun dance.*[1] JOHN C. EWERS, U. S. National Museum.

When George Catlin, the artist and Indian enthusiast, published (1841) the first graphic account of the practice of self-torture in a Plains Indian ceremony, which he had witnessed in 1832, his description was termed fantastic by D. D. Mitchell, Superintendent of Indian Affairs. Apparently shocked by Catlin's vivid portrayal of coolly premeditated self-sacrifice of human flesh and blood by participants in the Okipa ceremony of the Mandan, Mitchell declared, "The scenes described by Catlin, existed almost entirely in the fertile imagination of that gentleman" (Schoolcraft, vol. 3, p. 254; Catlin, vol. 1. pp. 157–177).

Catlin's description was substantiated, however, some years before Mitchell's accusations were made, by the Independent Mandan investigations of Prince Maximilian in 1833–34, (Maximilian, vol. 23, pp. 324–334). Catlin was defended strongly by the intelligent fur trader James Kipp, who had

[1] Received January 30, 1948.

been with Catlin when he witnessed the ceremony (Kipp, pp. 436–438).

Since the days of that historic controversy, the practice of self-torture in tribal sun-dance ceremonies has been reported, on reliable authority, as once characteristic of the Arapaho, Arikara, Assiniboin, Canadian Dakota, Cheyenne, Crow, Gros Ventres, Hidatsa, Oglala Dakota, Plains Cree, Plains Ojibway, Sarcee, Sisseton Dakota, and the three Blackfoot tribes (Spier, pp. 473–475). Furthermore, brief accounts have been published of ceremonial self-torture, witnessed as early as 1805, among the Arikara and Hidatsa by the fur traders Pierre-Antoine Tabeau and Charles Mackenzie (Tabeau, pp. 191–193; Mackenzie, pp. 354–357).

It seems most probable that some Plains tribes practiced forms of self-torture in the period before first white contact.

Among the Plains Indian tribes of the United States the practice of self-torture was prohibited more than 60 years ago. This ban resulted from the combined opposition of missionaries and the civil and military branches of the Federal Government to such self-imposed cruelties, which tended to excite the Indians, to perpetuate both Indian-white and intertribal hostilities, and to make difficult the process of civilization and Christianization of the Indians.

Published descriptions of self-torture among these tribes have been primarily of two kinds. Some were eye-witness accounts of interested but untrained white observers who not infrequently misinterpreted the purpose of the torture as a ceremony for "making braves." Others were based on the testimony of older Indians who had witnessed the tortures some years earlier but had not experienced torture themselves. Detailed case histories from the mouths of men who had submitted themselves to torture are few and fragmentary in the extensive literature on the sun dance.

Self-torture survived in the sun dances of the Blood and North Blackfoot Indians of southern Alberta for a few years after its discontinuance among the Plains tribes of this country. In the course of field work on the Blood Reserve in September, 1947, the writer met two elderly full-bloods who had been tortured in the sun dance of their tribe. They were the last survivors of men of that tribe who had experienced this ordeal, and they were particularly desirous that their torture experiences should be recorded accurately. These narratives by Scraping White (now 81 years old) and Heavy Head (now 78), related to the writer through the interpreter Percy Creighton, provide new and significant information on the procedure of self-torture in the Blood sun dance ceremony and its meaning to those who submitted to it. They help to round out the only published description of the Blood self-torture, that of the missionary John McLean, who witnessed the ceremony prior to 1889.

In the summer of 1889 the Blood medicine lodge was erected on the north bank of the Kootenay River, in southern Alberta. Three young men, Scraping White (then 23 years of age), Tough Bread (now deceased), and Heavy Head (then 20 years old), presented themselves to be tortured.

Scraping White described his experience thus:

> Three of us tortured ourselves in the sun dance that year—Tough Bread, Heavy Head, and I. I was the oldest of the three.
>
> I was on a war party to take horses from the Assiniboine when I made my vow to be tortured. Shortly before the sun went down, when we were in sight of the enemy camp, I turned to the sun and said, "I want good luck. Now I go to the enemy. I want to capture a good horse and go home safely. I'll be tortured this coming sun dance." As soon as it was dark I went into the enemy camp and took two fast horses out of their corral without any of them knowing it. I had good luck and reached home safely.
>
> Then I told my relatives of the vow I had made. Yellow Horn, an older relative, who had been through the torture before, told me, "Put up a sweat lodge for me and I shall look after you." I made the sweat lodge the very next day.
>
> Not long after that the sun dance was held. The torture took place the day after the center pole was raised for the medicine lodge. I was the first one to be tortured. The torture began about noon. Old Yellow Horn cut my breasts with an iron arrowhead and inserted a skewer through the cuts at each breast. These skewers were of serviceberry wood, flattened on both

sides, thinned toward the ends but not sharpened, and about this long. [Scraping White indicated a distance of about 2 inches between his thumb and forefinger.] Then sinew was wrapped around the ends of the skewers and they were tied, each skewer to a 4-strand plaited rawhide rope. The two ropes were fastened at their far ends to the center pole at its forks.

I stood up and Yellow Horn told me, "Now you walk up, put your arms around the center pole and pray. Tell sun, now your vow is being fulfilled." I did just as he told me. Then I stepped back. Yellow Horn pulled hard on the rawhide ropes attached to the skewers. Then I danced. I didn't dance long before my flesh gave way and the skewers pulled out. Yellow Horn came to me and cut the skin that had broken. He trimmed it off even. Then he gave me the pieces of skin he had cut away and told me to take them and stick them in the ground at the base of the center pole, saying, "Now sun, I have completed my vow."

Heavy Head's narrative of his torture experience was still more detailed:

There were only two of us, Buffalo Teeth, my partner, and I. We went to war together to take horses. At Medicine Hat we found a small camp of Cree half-breeds. It was night when we saw their camp. It was moonlight. I looked up at the moon and prayed to it, "I shall be tortured at the sun dance if I have good luck and get home safely." Then I stole up to the camp and got one bay that was tied in front of a lodge without any of the enemy waking or seeing me. Buffalo Teeth took a roan. We started back to the Blood camp, traveled three days and three nights with no food other than a black rabbit. We got awfully weak and hungry.

When I reached home I told my story to my father, Water Bull. The old man got up and sang his encouraging song. Then he told me, "My son, you have done something worth doing. You have made a vow that you will be tortured at the sun dance. You must do it this coming sun dance."

A few days later I went out to the east point of Belly Butte to fast. While I fasted I dreamed that a sacred person came to me and gave me a drum and certain herbs to use for doctoring. Then I returned home.

A short time after that the bands began to come together for the sun dance encampment. I prepared myself to go to an old man named Little Bear, a relative of mine, who had been through the torture himself, years before. I filled my pipe and took it to him. I gave him the pipe and a buckskin horse, and said, "Here is a horse for you. Keep this pipe too. I want you to look after me in the torture." When I gave him the pipe he put it down and went over to the next lodge. There were two old men there, Green Grass Bull and Red Bead. These men were not related to me, but they were both older than Little Bear, and both had been through the torture. Little Bear asked them to come to his lodge, to take my pipe and pray for me. After they prayed, they told me not to take any food or water the day I was to be tortured.

The day before the torture I ate or drank nothing. Next day I ate or drank nothing until after the torture. However, the three old men gave me some sagebrush to chew.

I was the last of the three Blood Indians to undergo the torture that day. Scraping White, who was the oldest, was first. Then Tough Bread, then I. I was the youngest. Inside the medicine lodge, on the west side of the center pole and north of the weather dancer's arbor, a shelter was built of sticks like a sweat lodge, covered with willow leaves. I went in there before noon of the day of the torture. I was laid on my back with my head pointed north. I was barefoot, and wore only a breechcloth made from a small, red, trade shawl purchased from the Hudson's Bay Company. There was a little bowl of white paint and another of black paint nearby. The three old men painted four black dots, one below the other, under each of my eyes. This was called "tear paint." If I cried the tears would run down there. Then they painted a double row of six black dots on each arm. They painted the symbol of the moon, points up, on my forehead in black. On the outside of each of my legs they painted a double row of six black dots. The rest of my body was painted white, also my face. They took some of the broad-leafed sagebrush from the ground inside the sweat lodge and bound it together, placed a wreath of it around my head, and bands of it around each wrist and ankle.

I was taken from the sweat lodge and laid upon a blanket on the ground at the north side of the center pole with my head to the north, my feet toward the center pole. Other people were told to keep back away from me. Then an old man named Low Horn was brought forward. He counted four of his coups. The three old men, Little Bear, Red Bead, and Green Grass Bull, held me—one at each arm, and one at my head. Red Bead took a sharp, iron arrowhead in his hand, and asked me, "How do you want me to cut them? Thick or thin?" I said, "Thin." (I learned later that this question

FIG. 1.—Scraping White (left) and Heavy Head (right), two men who were tortured in the Blood sun dance of 1889.

FIG. 2.—An act of self-torture in the Blood sun dance of 1891. Photograph by R. N. Wilson.

was always asked of the man undergoing the torture before his breasts were pierced, and the one doing the cutting always did just the opposite of the young man's request. So when I said "thin," Red Bead knew to make his incisions deep).[3] Red Bead gave four of his own war coups. He made no prayer. Then he pierced my breasts with the sharp arrowhead and inserted a serviceberry stick through each breast. The sticks were not sharp but flattened at the ends. The other two men held my arms as he cut and inserted the sticks. Blood flowed down my chest and legs over the white paint. Then Red Bead pressed the sticks against my body with his hands. They turned me around to face the sun and pierced my back. To the skewers on my back they hung an imitation shield, not so heavy as a war shield. The shield had feathers on it, but I don't remember how it was painted. It belonged to a man named Peninsula.

The ropes were brought out from the center pole and tied to the skewers in my breasts—right side first, then left side. Red Bead then grabbed the ropes and jerked them hard twice. Then he told me, "Now you go to the center pole and pray that your vow will come true." I walked up there. I knew I was supposed to pretend to cry. But oh! I really cried. It hurt so much. Coming back from the center pole I was shouting. Then, before I started to dance, I jerked the shield off my back.

I leaned back and began dancing, facing the center pole. It felt just like the center pole was pulling me toward it. I began to dance from the west toward the doorway of the sun lodge and back. Then, when the skewers did not break loose, the old men realized that the incisions had been made too deep. Red Bead came up and cut the outside of the incisions again so they would break loose. As I started dancing again the left side gave way and I had to continue dancing with only my right side holding. An old man named Strangling Wolf jumped up from the crowd and came toward me shouting. He called out four coups he had counted and jumped on me. The last rope gave way and I fell to the ground.

The three old men came to me and cut the rough pieces of flesh hanging from my breasts off even. They told me to take this flesh that had been trimmed off, and the sagebrush from my head, wrists, and ankles, and place them at the base of the center pole. I did as they told me.

[3] Jenness, pp. 54–5, reported the same contrariness of action on the part of the Sarcee surgeon when the suppliant pleaded for a "thin" cutting.

Then I took my robe and walked out of the medicine lodge alone. I went to a lonely place and fasted for a night. I wanted to dream. But I couldn't sleep at all because of the pain. At sunrise I prayed to the sun.

Some time after that I saw a man approaching on horseback. He said, "I'm going to take you home right away." He took me up behind him on his horse and rode me slowly back to camp. My breasts were swollen and hurt. The rider's name was Red Crane. He told me of a mix-up that took place at the sun dance over horses stolen from the Gros Ventres.

When I got to my lodge, my mother gave me something to eat. She and my father told me what had happened at the sun dance gathering—a mix-up between the Mounted Police and Indians.[3] I had to stay in the lodge several days. My breasts were so swollen I could hardly move. Indian doctors used herb medicines to take the swelling away and cure my wounds.[4]

The common elements in these two accounts reveal the pattern of the self-torture experience among the Blood Indians more clearly and completely than the brief description of the ordeal previously published by McLean. This experience was initiated by a warrior through a vow to the celestial deities, sun or moon (the latter in Blackfoot belief was sun's wife), very shortly before the man exposed himself to danger. The vow was a simple, direct appeal to the deity for protection and success in the immediate, hazardous undertaking. In return for such aid the petitioner promised to make the self-torture sacrifice in the sun dance lodge of his people. On return home after the successful exploit the pledger made known his vow to his relatives. They helped him to obtain the services of one or more older men who had been through the ordeal and were qualified, therefore, to instruct and care for the young man in the ceremonial fulfillment of his vow. The public cere-

[3] In the summer of 1889, the Mounted Police sought to apprehend Calf Robe, a Blood horse thief, who sought sanctuary in the medicine lodge of his people. The Indians overpowered the police and set Calf Robe free, but there was no bloodshed (Steele, pp. 262–265). This incident serves to verify the year of Scraping White's and Heavy Head's torture.

[4] These narratives follow as closely as possible the words of the interpreter. In a few places details obtained during further questioning of the informants have been inserted.

mony took place in the sun-dance lodge, about midday of the day following the erection of the center pole. One man was tortured at a time. Each young man's experienced helper or helpers prepared him for the ordeal, pierced his breasts, inserted the wooden skewers, and attached the thongs leading from the crotch of the center pole. They guided his actions by telling him first to embrace the center pole and pray for successful fulfillment of his vow, watched him closely until he freed himself from the ropes, trimmed off the ragged edges of flesh from his breasts and instructed him to place them at the base of the center pole as an offering to the sun. With this act the vow was fulfilled.

Both informants stated that the helpers were always men well advanced in years, rather than men who had been through the torture only a few years earlier. The number of helpers depended primarily on the age of the victim and his relative's confidence in his ability to take the punishment. Younger men generally had more helpers to hold them as the incisions were made. Fasting was not considered obligatory. Scraping White said he was not required to abstain from food on the day prior to the torture. Scraping White's narrative omits mention of the painting of his body in preparation for the torture. However, Heavy Head asserted that all who underwent the torture were painted just as he had been.

Neither Scraping White nor Heavy Head took any active part in the tortures at the sun dance of 1891, the last occurrence of self-torture in the Blood ceremony. They said that four men, Calf Tail, Buckskin Tom, Old Man Owl, and Takes Paint, all now deceased, were tortured in that year. R. N. Wilson, a trader on the Blood Reserve, photographed these torture ceremonies. One of his photographs is reproduced here, through the courtesy of Archdeacon S. H. Middleton, principal of St. Paul's Residential School, on the Blood Reserve, owner of a print from the original glass plate negative. Percy Creighton believed that the Indian shown in the act of torture was Takes Paint.

The Blood Indians were the last Blackfoot tribe, and probably the last tribe of Plains Indians to observe the self-torture ceremony. After their 1891 performance of the torture it was prohibited by the Indian Department and the Mounted Police. A year earlier the North Blackfoot had been persuaded to abandon torture (Ann. Rept., pp. 83–84). The Piegan eliminated torture from their sun dances at least 20 years earlier. Weasel Head (born about 1860), for many years a prominent weather dancer in the South Piegan sun dance, told the writer before his death in 1943, that he had never seen the torture performed in the sun dance of his tribe, although he recalled that as a youth he had seen older men who bore the scars of torture. Red Plume (born ante 1850), informed Curtis that he had seen the torture rites in the Piegan sun dance only four times, thrice when a small boy and once when a young man. Each time a single man had submitted to the torture. Red Plume attributed the discontinuance of self-torture in the Piegan sun dance to the warning of a North Piegan weather dancer that "they would die if they gave their bodies to the sun" (Curtis, vol. 6, p. 55). Clark Wissler (p. 262) and Walter McClintock (p. 320) reported the persistence of this belief among the Piegan in the first decade of the present century.

Wissler (p. 263) believed that self-torture had not become thoroughly adjusted to its place in the Piegan sun-dance ceremony at the time it was abandoned. On the other hand, the torture appears to have found much more favor among the neighboring Blood Indians. McLean (p. 236), stated that from two to five men underwent this torture every year in the Blood sun dance. Whereas the Piegan seem to have abandoned torture as a result of native fear and distaste for the ceremony, the Blood continued to practice it until they were compelled by Government authorities to give it up.

Wissler (pp. 263–264) was inclined to credit a Piegan tradition that the Blackfoot tribes borrowed the torture ceremony from the Arapaho. There still exist among the Piegan vague but persistent traditions of a group of Blood Indians who sojourned for a number of years with the Arapaho in the early part of the nineteenth century. Chey-

enne traditions, obtained from elderly men of the Southern Cheyenne nearly half a century ago by George Bird Grinnell and George E. Hyde, tell of a group of Gros Ventres and "Blackfeet" (division not indicated), who joined the Cheyenne and Arapaho in the Black Hills or on the Platte about the year 1826. According to one version of this tradition the "Blackfeet" returned north a few years later (Grinnell, vol. 1, pp. 39–40). Major Culbertson, who was married to a Blood woman, is reported to have found ten lodges of Blood Indians living with the Arapaho, when he attended the Fort Laramie Treaty Council in 1851. "They were unknown to him, and he did not learn how long they had been there or whether they ever returned" (Bradley, Book A, p. 184). These data, and the fact that the Piegan were relatively indifferent to the torture in later years, suggest the possibility that the torture feature was introduced among the Blackfoot tribes by Blood Indians, who may have borrowed it from the Arapaho no earlier than the second quarter of the nineteenth century.

Spier (p. 491) regarded the self-torture as a nonessential element in the sun-dance ceremony of most Plains tribes. Our evidence certainly supports this conclusion insofar as the Blood sun dance is concerned. Both the torture pledger and his helpers played no necessary part in the sun-dance ceremony. They entered the medicine lodge for the sole purpose of fulfilling the pledger's vow. The Blackfoot tribes have continued their annual sun dances to the present day, with no apparent sense of loss of any essential feature. Now as formerly the sun dance centers about the elaborate ritual prescribed for the fulfillment of the vow of the medicine woman who pledged the ceremony. Her objective was reached with the completion of the medicine lodge, the day before the tortures took place.

The Blackfoot tribes regarded the torture, such as was endured by Scraping White and Heavy Head, as the most dangerous and severe form of physical sacrifice to the sun. The mutilation of the body by offerings of a finger or bits of flesh from the arms and legs were considered lesser ordeals (Wissler, pp. 263–265). Scraping White showed the writer scars on his legs resulting from the sacrifice of pieces of flesh to the sun prior to the year of his torture experience. Nevertheless, the belief of the Piegan that men who submitted to the torture would not live long after they had given their bodies to the sun, appears to have been based upon religious fear rather than the life histories of men who had been tortured. Several of our elderly South Piegan informants recalled having seen older men of the tribe who bore the scars of the torture. The severity of the torture varied with the depth of the incisions. Older men watched the suppliant carefully, and did not permit the torture to be prolonged indefinitely. Even in the case of Heavy Head, whose experience was described by other elderly Blood Indians as the most severe punishment they had witnessed in sun-dance tortures, the performance lasted only a few minutes. His narrative indicates the pain and nervous shock must have been intense. But in the majority of cases it probably did no permanent damage to the individual. Although Scraping White and Heavy Head still bear the scars of their torture, these men appear to be in fair health, active of mind and body, nearly six decades after they expiated their vows to the sun in the Blood medicine lodge in the summer of 1889.

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PALEONTOLOGY.—*On two previously unreported selachians from the Upper Cretaceous of North America.*[1]

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(Communicated by C. LEWIS GAZIN.)

Recently, the U. S. Geological Survey transferred to the National Museum two interesting toothlike fossils obtained by Dr. L. W. Stephenson during the course of his prolonged geological investigations on the Cretaceous formations of Texas. These specimens have proved to be examples of the structures currently interpreted as rostral teeth of pristid sharks. They are assignable to the genera *Onchopristis* Stromer and *Schizorhiza* Weiler, both of which were founded on materials from various upper Cretaceous horizons and localities in North Africa. In the Western Hemisphere, *Onchopristis* has not heretofore been known and *Schizorhiza* only from a single, doubtful report from the upper Senonian of Chile (Wetzel, 1930; and Weiler, 1930).

The definitive record of the fossil Pristidae in North America is confined to the isolated rostral armament of *Pristis* from the Cretaceous and a number of Tertiary horizons. In addition, during recent years the problematical genus *Ischyrhiza* has been included here. In the Eastern Hemisphere no less than 12 genera of fossil pristids are recognized. The majority of these are founded on isolated rostral teeth and their assignment to the family Pristidae, oftentimes doubtfully, has been based on the nature of their insertion onto the rostral cartilages as shown by gross morphological features and by histological considerations. The present two specimens can not lend themselves to histological preparation without destruction, and little of general morphological and systematic information can be deduced from them. However, the new occurrences in essential stratigraphic contemporaneity with their North African genotypes seems of sufficient interest to warrant the following brief description.

The illustrations accompanying this note have been prepared by Mrs. Elinor Stromberg, scientific illustrator of the U. S. Geological Survey.

Onchopristis cf. *numidus* (Haug)

A single unassociated tooth (U.S.N.M. no. 17088), although with only one side exposed and lacking the distal extremity, exhibits well the characteristics of the genus as defined by Stromer (1917).

The structure is strongly compressed, dorsoventrally, and is composed of a short inserted base and an exposed, enamel-covered crown. The line of demarcation between these two parts is prominent, being remarked by a constriction of the base adjacent to the proximal limit of the enamel. This latter shows a border arched in gentle convexity toward the base and extended obliquely across the long axis of the element. The preserved portion of the crown possesses one posterior barb. Both anterior and posterior margins of the crown form sharp cutting edges except at the proximal reentrance of the barb where the edge is bluntly rounded. The enamel on the slightly convex, exposed surface of the tooth is checked both

[1] Published by permission of the Secretary of the Smithsonian Institution. Received January 30, 1948.

FIG. 1.—*Onchopristis* cf. *numidus* (Haug) (U.S.N.M. no. 17088). Rostral tooth from the Woodbine formation of Texas. Approx. ×4.

longitudinally and transversely as a result of weathering but exhibits no observable ornamentation. The base, in dorsoventral aspect, is expanded and is marked by a few regularly spaced furrows, which are extended in the direction of the longest axis of the tooth.

Measured in relation to the longest axis, the specimen has the following dimensions: Total preserved length, 13.7 mm; greatest length of base, 4.5 mm; maximum width of base, 8.4 mm; width of crown immediately below barb, 6.0 mm; and greatest thickness of crown on fractured distal exposure, 2.4 mm.

Remarks.—The systematic history of *Onchopristis numidus* (Haug) has been completely summarized by Stromer (1917). The present example from Texas differs from the North African specimens in the shortness of that portion of the enameled crown proximal to the barb. Stromer (1917, 1925, and 1927), however, in his discussions on this sawfish, has demonstrated wide variation between individual rostral teeth and has described examples with multiple posterior barbs. In consequence there seems to be no immediate basis for erecting additional species within the genus.

Geological horizon and locality.—Collected from the Upper Cretaceous (Cenomanian) in the Lewisville member of the Woodbine formation, approximately 2.4 miles southwest of Lewisville, Denton County, Tex., by L. W. Stephenson, October 25, 1945.

Distribution.—All the North African occurrences of *Onchopristis* are considered by Stromer to be of Cenomanian Age.

Schizorhiza cf. weileri Serra

To this form is assigned a small imperfectly preserved tooth (U.S.N.M. no. 17087). The complete outline of one side of the specimen is clearly impressed in the limy sandstone matrix, although almost all the tooth tissue from that side has been lost. The opposite side of the tooth is deeply imbedded in the matrix of the counterpart. As thus incompletely exposed it was necessary to crack the counterpart in two and examine the cross section of the imbedded part before any structural interpretation could be made.

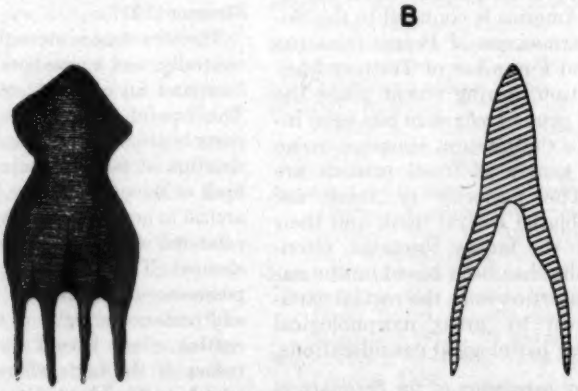

FIG. 2.—*Schizorhiza* cf. *weileri* Serra (U.S.N.M. no. 17087). Rostral tooth from the Escondido formation of Texas in (*A*) dorsoventral aspect as restored from a cast of the preserved impression and in (*B*) ideal transverse section. Approx. ×4.

It is assumed that this tooth projected laterally from firm attachment along the edge of a rostrum. In orientation, therefore, the long axis of the tooth is a transverse dimension, and this breadth exceeds the shorter length by about three times. The element is moderately compressed, dorsoventrally, and the top and bottom halves are apparently symmetrical. The crown occupies approximately one-third the longest axial dimension, and from the shiny smoothness of its impression is indicated to have been enamelled. It projects directly out in the frontal plane of the tooth without dorsad or ventrad flexure; is arched very slightly toward the rear; and is basally emarginated at the anterior and posterior edges. The free lateral margins are sharp, straight, and converge to an obtuse distal point. The root, viewed either dorsally or ventrally, is seen to expand proximally from a narrow distal neck. The part is divided into flat upper and lower lips by a frontal groove which extends outward nearly to the base of the crown. Three furrows traverse the outer surfaces of both upper and lower lips, parallel to the long axis of the element. These grooves are continued proximally as deep notches in the inner edges of the root lips. Thus, mesially, the lips are each produced into four acutely conical projections, of which the central two are the longest.

Measured in relation to the longest axis, the tooth possesses the following dimensions: Total length 15.0 mm; length of crown, 4.0 mm; maximum width of crown, 5.0 mm; maximum width of root, 6.0 mm; length of longer proximal rays, 5.5 mm; and depth of proximal divergence of root lips, 6 mm.

Remarks.—The genus *Schizorhiza* is known only from isolated teeth and the genotype is the species *stromeri* (Weiler, 1930). In addition to some Egyptian specimens, Weiler included in his original description a number of fragmentary teeth from several widely scattered localities (Di Stephano, 1919; Quaas, 1902; and Wetzel, 1930). This type series presented a range of structural variation from teeth as here described to examples which in gross features appear similar to *Ischyrhiza*, with long tapering, scimiterlike crowns and robust roots exhibiting only a shallow frontal groove. Apparently no one specimen among those was designated the type. Subsequently, Serra (1933) abandoned the name *stromeri* for all of the teeth of the type series except that pictured by Weiler in his Fig. 1a, Pl. II. In return, the specific name *weileri* was proposed for the tooth illustrated as Fig. 3a, Pl. II, and a collection of identical specimens from Sofeggin, Tripolitania.

Of these two species, the present Texas specimen is more closely comparable with *weileri*. It differs from it only in the more pronounced asymmetry of the crown profile in dorsoventral aspect and in exhibiting a greater size than reported by Serra. Provisional assignment to the latter species is therefore made. While possibly representing a new species, it does not seem advisable to establish a type on this, an incomplete tooth heretofore unrecorded from North America. A more critical evaluation will depend upon the acquisition of a series of the Texas specimens which permit qualitative studies and histological examination.

Geological horizon and locality.—Collected from the Upper Cretaceous (Maestrichtian) in the Escondido formation, 2 miles east of Eagle Pass, Maverick County, Tex., by L. W. Stephenson, October 30, 1912.

Distribution.—Weiler (1930) gave a Senonian Age to all the teeth from North Africa, Arabia, and Chile on which he based his definition of *Schizorhiza stromeri* (*sensu lato*). Serra (1933) considered the occurrence of *S. weileri* as Maestrichtian.

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ENTOMOLOGY.—*Synoptic revision of the United States scarab beetles of the subfamily Dynastinae, No. 4: Tribes Oryctini (part), Dynastini, and Phileurini.*[1]

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This paper is the fourth in the series of my United States dynastine scarab beetle studies and completes the specific listings and notes. The fifth, and last, part will include a complete classification of the tribes and genera, from the Nearctic standpoint.

Genus **Aphonus** LeConte

Aphonus LeConte, 1856, p. 21; Horn, 1882, p. 122; LeConte and Horn, 1883, p. 259; Casey, 1915, pp. 178, 210; Ritcher, 1944, p. 28, Cartwright, 1944, p. 36.

Podalgus (part) Burmeister, 1847, p. 117; Lacordaire, 1856, p. 408.

Aphonus (as now constituted) is limited to the Eastern United States and contains four valid species; the farthest west I have knowledge of the genus occurring is Texas, where *brevicruris* Cartwright was collected.

The only character separating the adults of *Aphonus* from United States species of *Cheiroplatys* Hope is the trilobed (varying to subtridentate to even simply carinate in worn examples) preapical carina of the clypeus. In the larvae, Ritcher has pointed out (1944) the very close similarity between *Cheiroplatys pyriformis* LeConte and *Aphonus castaneus* (Melsheimer), the only real difference being that the first antennal segment in the latter is bare of setae, and the other two key characters being those of degree only (relative distance between lobes of the thoracic spiracle, respiratory plate, and width of the head capsule). In the adults, the peculiar preapical carina and the rather odd apical, front tibial tooth, as well as external facies and proportions in general, immediately disclose the close affinity of the two groups at present called *Aphonus* and *Cheiroplatys*. Indeed, I have relatively fresh specimens of *A. castaneus* (from Massachusetts and New Hampshire) in which the preapical clypeal carina is distinctly *bidentate*, so that the only character for the retention of the name *Aphonus* as a valid genus is gone.

However, even though I feel that *Aphonus* must eventually be considered a synonym of the earlier described *Cheiroplatys* I am unable definitely to synonymize the two genera until I can review the genotypes; I desire also to dissect carefully the mouthparts of many of the Neotropical and Australian forms of the genus.

The sexes of *Aphonus* are rather similar in most characters, but in the male the last abdominal sternite is shorter and is feebly but distinctly emarginate apically, whereas the last abdominal in the female is longer and the apex is evenly rounded.

I have been unable to construct a satisfactory key to the species based on nonvariable external differences, so that to place the species properly it is necessary to make genital dissections. The only general statement that can be made as to the external facies is that *castaneus* is most frequently rufous, averages 10 to 11 mm in length, and is more robust; whereas *densicauda* and *tridentata* are both more elongate, and the former averages 13 mm in length and the latter 15 mm. Obviously, such generalities are interesting but of little assistance in actually separating closely allied and variable species. According to Cartwright's description of *brevicruris* (the unique type of which I have not seen) the proportions of the heavy, short tibia and femora will readily separate this species from all other described forms.

[1] Received September 3, 1947.

Aphonus castaneus (Melsheimer)
FIG. 1, *k*, *m*

Bothynus castaneus Melsheimer, 1856, p. 138; LeConte, 1856, p. 22.
Podalgus obesus Burmeister, 1847, p. 119; Arrow, 1909, p. 341.
Aphonus castaneus (Melsheimer) Casey, 1915, p. 220; Sims, 1934, p. 334 (larvae); Johnson, 1942, p. 79; Ritcher, 1944, p. 30, pls. 2–5 (larvae).
Aphonus cubiformis Casey, 1915, p. 221.
Aphonus saginatus Casey, 1915, p. 220.
Aphonus trapezicollis Casey, 1915, p. 219.

All examples of this small species that I have examined vary from rufocastaneous to piceocastaneous in color, and from 8 to 13 mm in length. The species ranges generally along the East Coast from Maine south through the Carolinas, Georgia, and Alabama. Johnson mentions finding numerous larvae on the surface of a Connecticut golf course during a gentle July rain, and these larvae retreated into the sod when the sun reappeared. Sims records the larvae as common in the turf of the coastal plains golf courses and in sandy soil generally.

Aphonus densicauda Casey
Fig. 1, *h*, *l*

Aphonus densicauda Casey, 1915, p. 216; Ritcher, p. 31 (larvae).

Described from Pennsylvania, and seen also from New Hampshire, south to Georgia and Kentucky and west to Iowa; will probably be found to have a much wider distribution than indicated by available specimens. Ritcher records it as fairly common in Kentucky where full-grown larvae may be found in pastureland, in or just beneath the sod, from November to May, and pupation occurs late in May or early in June; he found adults in the soil throughout the year.

The color is usually piceous or piceocastaneous, varying to rufous, as do all species of the genus, and the length averages 13 mm. The adults are hard to separate from typically black *tridentatus* other than on genital characters and the slightly larger average size of the latter (15 mm.); the larvae are also very similar but distinct according to Ritcher (1944).

Aphonus tridentatus (Say)
Fig. 1, *f*, *i*, *j*, *n*

Scarabaeus tridentatus Say, 1823, p. 209.
Bothynus variolosus LeConte, 1848, p. 88 (new synonymy).
Aphonus tridentatus (Say) Horn, 1882, p. 122; Casey, 1915, p. 215; Ritcher 1944, p. 33 (larvae); Arrow, 1937, p. 42 (additional refs.).
Aphonus aterrimus Casey, 1915, p. 216.
Aphonus congestus Casey, 1915, p. 218.
Aphonus elongatus Casey, 1915, p. 215.
Aphonus frater LeConte, 1856, p. 22.
Aphonus hydropicus LeConte, 1856, p. 22.
Aphonus ingens Casey, 1924, p. 334.
Aphonus modulatus Casey, 1915, p. 219.
Aphonus politus Casey, 1915, p. 218.
Aphonus scutellaris Casey, 1924, p. 335.

Usually piceous, this largest United States species of the genus varies to entirely rufous, especially in specimens from Florida, and these latter are the *variolosus* of LeConte; the Florida specimens are often 2–3 mm smaller than the more northern specimens and superficially look different, but the genitalia and all essential diagnostic characters are identical and I have no doubt of the correctness of the synonymy. I have seen specimens from Michigan, Indiana, Illinois, south through Georgia, South Carolina, and Florida; also recorded from New York and Wisconsin. Cartwright has taken numbers at Clemson, S. C., from March through July. Ritcher says that the larvae are found in woodland loam; collected by Yeager from "forest duff" in Michigan.

Aphonus brevicruris Cartwright
Fig. 1, *e*

Aphonus brevicruris Cartwright, 1944, p. 36, pl. 1, fig. 5.

Described from a unique male collected at Austwell, Tex., May 20, 1941 (Goodpaster collector), and not taken since to my knowledge. I have not seen the type, and the information here is reworded and taken from Cartwright's paper: Easily separable from all other United States species by the proportions of the hind legs: the femur is three-fifths as wide as it is long, the tibia is *shorter* than the femur, and the tibial apex is widely flared and *more than* half as wide at apex as the full tibial length; in all other United States species the hind femur is only *half* as wide as long, the hind tibia and femur are *subequal* in length and the hind tibial apex is flared but at most is one-third as wide at apex as the length.

Tribe DYNASTINI

Some of the largest and heaviest insects in the world occur in this tribe, including

the well-known *Dynastes hercules* of the American Tropics. Arrow (1937) lists only 21 genera in the tribe from the world, many of these genera being monobasic. The essential character of the enlarged male forelegs is not too well shown in our United States species, but in our relatively common *Golofa* Hope and such *Megasoma* as *elephas* the character is strongly indicated. In the Colombian *Golofa porteri* Hope the front legs in the male are as long as the entire body and exactly twice as long as the forelegs of the females. Bates (1889) reports the immense *Megasoma elephas* (Fabricius) as feeding in numbers on ripe mangoes in Panama, and my father has collected numbers around street lights in central Panama, where the large lumbering insects often fly into the faces of passersby and occasionally badly scratch or at least scare them! Since a large male specimen weighs nearly half a pound, the bruises and abrasions that could be occasioned by such a specimen flying into a person's face is easily imaginable.

We have only two genera in the United States.

KEY TO UNITED STATES GENERA

First segment of hind tarsus sharp on outer side but not really extended into a long spine (length of segment on *outer* side exclusive of apical movable setae only one-third to one-fifth longer than length on *inner* side); prosternal spine high between front coxae (as "tall" as its own width across base) and always either densely hairy or at least hairy or setose apically on posterior side; surface glabrous and usually gray, speckled with piceous spots (rarely unicolorous in some females); male with front thoracic angles normal, that is, not sinuous (southeast and southern United States and Mexico) ..... *Dynastes* Kirby

First segment of hind tarsus with a long distinct apical spine (length of segment on outside, including spine, one-half to three-fourths times longer than length on inner side); prosternal spine much shorter than coxal length (two-thirds as "tall" as its own width across base) and always quite glabrous on external face; surface always hairy (velvety) and unicolorous piceous; male with each front thoracic horn strongly sinuous (Arizona and Mexico) ..... *Megasoma* Kirby

Genus **Dynastes** Kirby

Dynastes Kirby, 1825, p. 568; Burmeister, 1847, p. 256; Lacordaire, 1856, p. 444; Casey, 1915, p. 258; Arrow, 1937 (many references given), p. 95; Ritcher, 1944, p. 39 (larvae).

Our species have been variously listed or described in the genera *Scarabaeus*, *Geotrupes*, *Xylotrupes*, and others by the older authors and such references are readily available in Arrow (1937) and Burmeister (1847).

Arrow lists 13 species of these so-called "rhinoceros beetles" as valid in his 1937 catalogue, these occurring in India, the Philippines, Java, Burma, Borneo, Nigeria, the Congo, and the Americas. I seriously doubt that all these could possibly be congeneric. At any rate, six species are listed from the Americas, and two of these are supposed to occur in the United States. The large and well-known *hercules* apparently has not been taken yet north of Guatemala, except possibly in quarantine interceptions, and it appears to be replaced in Mexico by the much smaller so-called *hyllus* of Chevrolat. I have seen specimens of the latter species from central and southern Mexico and am entirely unable to separate them either on genital or external characters from our common *tityus* (Linnaeus).

Our Arizona *Dynastes* are usually called *granti* Horn; the male genital characters are *identical* with those of *tityus* and the only differences can be summed up in the following (the thoracic horn is measured with a micrometer scale in a direct line between the laterobasal denticles at each side of the horn base, and the horn apex):

Male thoracic horn *distinctly* 6–8 times *longer* than scutellar length (19–23 mm/3 mm); this horn also much broader basally through the denticles; horn on head long, with a very distinct and large, preapical tooth on the dorsal side (Arizona) ..... *granti* Horn

Male thoracic horn 3–5 times longer than scutellar length (7–12 mm/2.5 mm); horn of head usually *faintly* notched dorsally or entirely smooth, never with a dorsal preapical tooth. Eastern United States and Mexico ..... *tityus* (Linnaeus)

As anyone who has worked to any extent in the Dynastini knows, these characters as listed above are highly variable in a group where exceptionally dimorphic forms are the rule rather than the exception, and I am not at all sure of the validity of *granti*. We have an exact counterpart of this in the related and well-known *Golofa imperialis* Thomson and *pizarro* Hope where the males are unusually variable and the thoracic horn in *male majors* is unusually long and toothed within, varying through all degrees to the *male minors*, in which the horn is

the merest sort of a knob with a smooth inner surface. Until such time as exact intermediate specimens can be collected between Arizona and the more typically eastern *tityus*, it appears best to retain the name *granti* as a weak subspecies of *tityus*.

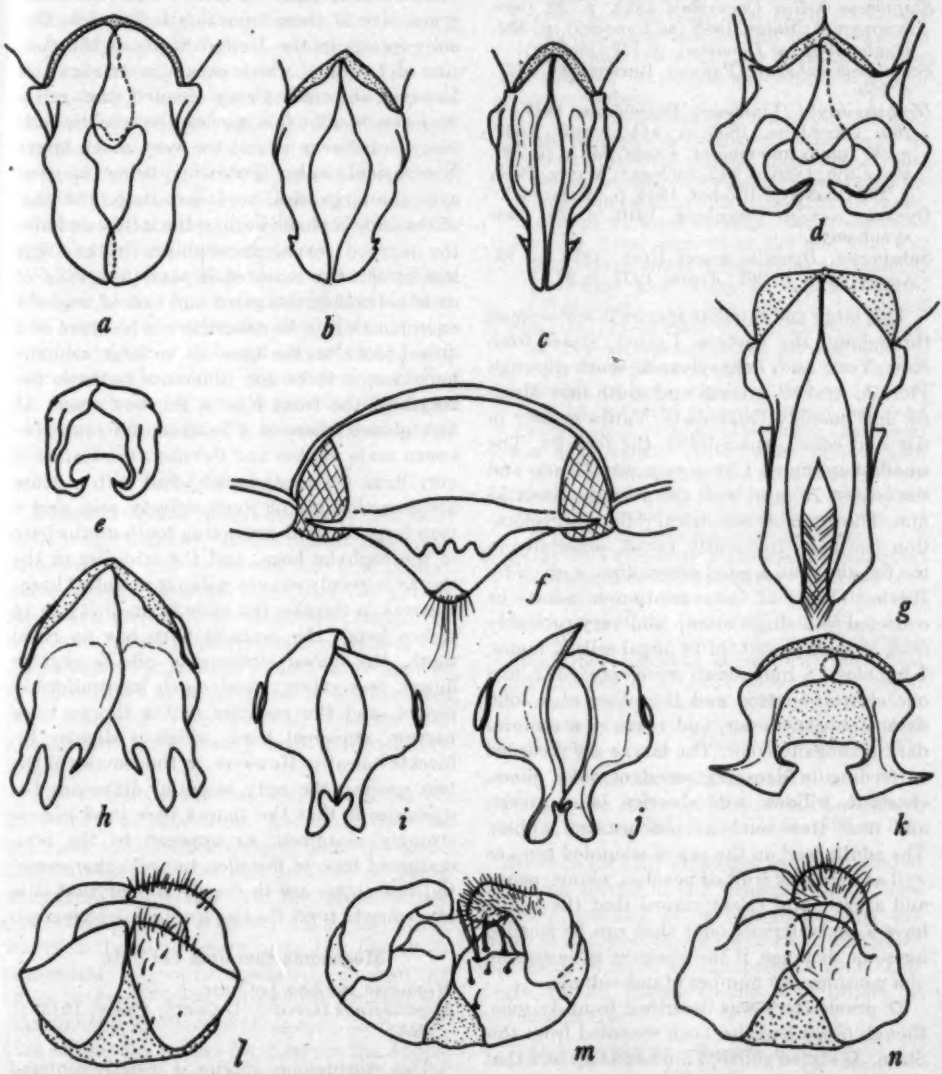

FIG. 1.—*a*, *Phileurus truncatus* (Beauvois): Male genitalia; *b*, *Archophileurus cribrosus* (LeConte): Male genitalia; *c*, *Phileurus illatus* LeConte: Male genitalia; *d*, *Phileurus castaneus* Haldeman: Male genitalia; *e*, *Aphonus brevicruris* Cartwright: Male genitalia; *f*, *Aphonus tridentatus* (Say): Head of female, front view; *g*, *Dynastes tityus* (Linnaeus): Male genitalia; *h*, *Aphonus densicauda* Casey: Male genitalia; *i*, *Aphonus tridentatus* (Say): Male genitalia, from Jacksonville, Fla.; *j*, *Aphonus tridentatus* (Say): Male genitalia, from South Carolina; *k*, *Aphonus castaneus* (Melsheimer); Male genitalia; from Rhode Island; *l*, *Aphonus densicauda* Casey: Female genitalia; *m*, *Aphonus castaneus* (Melsheimer): Female genitalia; *n*, *Aphonus tridentatus* (Say): Female genitalia.

Dynastes tityus (Linnaeus)
Fig. 1, *g*

Scarabaeus tityus Linnaeus, 1763, p. 391.
Scarabaeus marianus Linnaeus, 1767, p. 549.
Scarabaeus pennsylvanicus DeGeer, 1774, p. 308.
Scarabaeus hyllus Chevrolat, 1843, p. 33 (new synonymy); Bates, 1888 (as *Dynastes*), p. 336; Dugès, 1887 (as *Dynastes*), p. 137 (biology).
Scarabaeus iphiclus (Panzer) Burmeister, 1847, p. 259.
Dynastes tityus (Linnaeus) Burmeister, 1847, p. 260; Lacordaire, 1856, p. 444; Arrow, 1937, p. 98 (many references); Casey, 1915, p. 260; Hamilton, 1886, p. 112 (biology); Manee, 1915, p. 266 (biology); Ritcher, 1944, p. 39 (larvae).
Dynastes corniger Sternberg, 1910, p. 26 (new synonomy).
Subspecies: *Dynastes granti* Horn, 1870, p. 78; Casey, 1915, p. 261; Arrow, 1937, p. 97.

This large and familiar species is widespread throughout the eastern United States from New York and Pennsylvania south through Florida, west to Arizona and south into Mexico, and possibly Guatemala. Varies greatly in size and color, especially in the females. The smallest specimen I have seen was 37 mm and the largest 74 mm; with the average about 55 mm. The often asymmetrical (bilateral) coloration has been frequently noted, especially in the females, and a good description is given by Ritcher (1944) of this variation in adults he collected in a single stump and very probably from a single parent: in 14 pupal cells (7 males, 7 females), 8 individuals were spotted, 5 had one elytron spotted and the other of a solid dark mahogany color, and 1 was of a uniform dark mahogany color. The larvae are recorded as feeding in decaying wood of oaks, pines, chestnut, willows, wild cherries, black locust, and fruit trees such as peaches and apples. The adults feed on the sap of wounded trees as well as decaying fruit of peaches, plums, pears, and apples, and Casey claims that the adults have a characteristic odor that can be smelled for some distance, if the observer is downwind of a considerable number of individuals.

D. granti Horn was described from Arizona, though *tityus* has also been recorded from this State. As stated above, I am not at all sure that the form is sufficiently distinct to warrant its retention.

Genus **Megasoma** Kirby

Megasoma Kirby, 1825, p. 566; LeConte and Horn, 1883, p. 260; Casey, 1915, p. 261; Arrow, 1937, p. 98 (other references).
Megasominus Casey, 1915, p. 261; Arrow, 1937, p. 35.
Megalosoma Burmeister, 1847, p. 273.
Lycophontes Bruch, 1910, p. 73.

Arrow lists eight species of this American genus, five of them from South America. Our only species in the United States is the *thersites* of LeConte, which occurs in Arizona and Lower California. Casey erected the genus *Megasominus* for this species, the essential differences between it and the very much larger Neotropical *elephas* (Fabricius) being the presence of a large basal horn dorsally on the base of the male cephalic horn in the latter, and also the marked sexual dimorphism in the front legs of the two sexes of *elephas* (fore tibia of male noticeably elongated and curved, and not so in female); in *thersites* there is no trace of a dorsal tooth on the base of the large cephalic horn, nor is there any difference between the length of the front legs in the two sexes. At first glance, there is a marked difference between male *elephas* and *thersites:* the former is very large (3½ to 4½ inches) and with a dense uniform clothing of short velvety pile, and a very large forward-projecting tooth on the base of the cephalic horn, and the mid-disc of the thorax is evenly convex without a central horn; whereas in *thersites* the male is small (1¼ to 1½ inches long), the cephalic horn has no basal tooth, the dorsal clothing of pile is slightly longer, less velvety, and much less uniformly placed, and the mid-disc of the thorax has a narrow, semierect horn, which is slightly bifurcate apically. However, in the females of the two species, the only essential difference besides size is that the thorax base in *elephas* is strongly margined, as opposed to the nonmargined base of *thersites*, but all other essential characters are so closely similar that it is necessary to treat the two species as congeneric.

Megasoma thersites LeConte

Megasoma thersites LeConte, p. 336.
Megasominus thersites (LeConte) Casey, 1915, p. 259.

This uncommon species is usually confined to Lower California, but I have a specimen taken in the "Coyote Mts., Arizona, August, 3,500 ft. elevation." Ross and Bohart collected the species at San Venancio in Lower California on October 8, 1941. Easily separable in the male from all other United States Dynas-

tini by the combination of the strongly bifurcate clypeal horn, and the sharp tooth of each front thoracic angle, as well as the moderate to short, narrow, erect, weakly bifurcate horn of the mid-disc of the thorax. The female is readily separable from female *Strategus* by the *widely separated* front teeth on the apex of the clypeus (one at each side angle) as well as the sharp, bidentate mandibles and the non-margined center base of the thorax. The female *thersites* somewhat resembles a female *Aphonides dunnianus*, but the clypeus there is unidentate at apex and the mandibles are equally rounded and not at all toothed. The life history is apparently unknown.

It is very surprising to me that the male aedeagus of this species is inseparable in form from that of male *Dynastes tityus*, but such appears to be the case, based on my own careful dissections; throughout dynastines generally, the characters of the male genitalia appear to be specific within narrow boundaries of variation.

Tribe PHILEURINI

This tribe is the most aberrant of the subfamily Dynastinae, as the labial palpi are inserted on the *underside* of the ligular plate instead of *at the sides*, and the generally black color and the depressed (majority of species) dorsal surface is suggestive of the Passalidae. Numerous genera and species are described and the tribe is world-wide; our American (Neotropical) species and genera are very poorly and inadequately known.

The two sexes are not well differentiated externally in this tribe. The only obvious external sexual difference is that the male sixth abdominal sternite (instead of being emarginate apically as in most other dynastine tribes) is subtruncate at apex, whereas the same sternite in the female is somewhat narrowly rounded, though at times it is practically impossible for even an experienced student of the group to be certain of the sex unless he dissects the specimen. This condition, however, does not hold good throughout the tribe, since males of the Neotropical *Amblyodus* Westwood show the typical emargination of the last sternite.

KEY TO UNITED STATES GENERA AND SPECIES

1. Completely lacking any tubercles or horns on either head or thorax; clypeal base consisting of a wide carina which is obsolescent laterally; front not at all concave, but coarsely punctate; side of thorax exceptionally hairy (hairs really extend from beneath thoracic margin); elytra short and very coarsely cribrate; apex of hind tibia slightly irregular but not really toothed; all tarsal segments short and subrectangular in shape; elytra "soldered" at sutures and wings reduced to mere vestiges. . . . . *Archophileurus cribrosus* (LeConte)

With tubercles or horns on either head or thorax or both, without transverse clypeal carina; front always strongly concave; elytra longer, depressed; hind tibial apex distinctly spinose, at least at sides; tarsal segments longer, basal segment of mid and hind legs with strong apical spine; elytra not soldered at suture and wings of normal length. (*Phileurus*) 3

2. Size large (29–34 mm); clypeal horn very large, as long as exposed dorsal portion of head, each horn situated right *at* and *on* lateral margin of head; small canthus in front of eye (dorsal view) very obsolescent, not at all conspicuous. . *Phileurus truncatus* (Beauvois)

Size much smaller (16–23 mm); clypeal horn small or represented by a tubercle, always much shorter than head length; clypeal horn situated *inside* each lateral margin, and not *at* it; eye canthus moderate to strong. 3

3. Front tibia distinctly 4-dentate, the subapical and apical external teeth very narrowly separated by a distinctly U-shaped incision; the sides of the "incision" parallel. . . . . *Phileurus castaneus* Haldeman

Front tibia tridentate, at most with the merest suggestion of a fourth tooth (near base if present) apical and subapical external tooth separated by a *wide* non-parallel-sided emargination. . . . . *Phileurus illatus* LeConte

Genus Archophileurus Kolbe

Archophileurus Kolbe, 1910, p. 334; Casey, 1915, p. 271; Arrow, 1937, p. 38; Cazier, 1399, p. 170.

Arrow in his 1937 catalogue lists a number of American species in this genus, some of these however actually being synonyms, but the group is not well enough known to definitely list them as such at the present time. Our single United States species also occurs in northern Mexico:

Archophileurus cribrosus (LeConte)

Fig. 1, *b*

Phileurus cribrosus LeConte, 1854, p. 80; Bates, 1887, p. 338.

Archophileurus cribrosus (LeConte) Casey, 1915, p. 264; Arrow, 1937, p. 87; Cazier, 1939, p. 170.

Judged from collected specimens apparently the center of distribution of this species is in

northern Mexico (Durango, Coahuila, and Tamaulipas), with further distribution in the southwestern United States (Texas, Arizona, and New Mexico). Nothing is known regarding its habits. The slender vestigial wings are interesting, and owing to this flightless condition we might expect to find local races in such a wide-ranging form.

Genus **Phileurus** Latreille

Phileurus Latrielle, 1807, p. 103; Burmeister, 1947, p. 148; Lacordaire, 1856, p. 456; Kolbe, 1910, p. 336; Casey, 1915, p. 264; Arrow, 1937, p. 89; Cazier, 1939, p. 170.

In his 1937 catalogue Arrow lists 27 species, at least 10 of which are known to me to be synonyms. The species range generally throughout the Americas and the West Indies. The larvae live in decaying wood. Because of the flattened dorsal surface and the black color, these *Phileurus* are often mistaken for passalid beetles, which they do indeed superficially resemble.

Phileurus truncatus (Beauvois)
Fig. 1, *a*

Scarabaeus truncatus Palisot de Beauvois, 1807, p. 41.
Phileurus truncatus (Beauvois) Casey, 1915, p. 265; Bates, 1889, p. 340; Arrow, 1937, p. 90; Cazier, 1939, p. 170.
Phileurus recurvatus Casey, 1915, p. 266.

Recorded by Bates and Casey from Mexico and ranging also rather commonly throughout our southeastern United States. Has been recorded as mistaking chimneys for hollow trees and thus falling into fireplaces. The large size and strong cephalic horns readily place the species.

Phileurus illatus LeConte
Fig. 1, *c*

Phileurus illatus LeConte, 1854, p. 80; Casey, 1915, p. 267; Ritcher, 1944, p. 47 (larvae).
Phileurus vitulus LeConte, 1866, p. 80; Cazier, 1939, p. 170.
Phileurus phoenicis Casey, 1915, p. 267; Cazier, 1939, p. 170.
Phileurus puncticollis Casey, 1915, p. 268; Cazier, 1939, p. 170.
Goniophileurus femoratus (Burmeister) Kolbe, 1910, p. 149, p. 344 (pars); Arrow, 1937, p. 86, 90; Blackwelder, 1944, pp. 257–258; Cazier, 1939, p. 170.

There has been a great deal of controversy about and incorrect citations for this species since Kolbe erected the genus *Goniophileurus* for *femoratus* Burmeister and placed *illatus* LeConte and *vitulus* LeConte as synonyms of it. Burmeister's types of *femoratus* were from French Guiana and this name (the species is unknown to me) should apply to that locality, and *vitulus* and *illatus* should be removed from the synonymy of that species. Kolbe's main character for the genus *Goniophileurus* was the 2- or 3-toothed mandible, whereas my dissections show without doubt that the mandibles of our U. S. species are quite *simple*. Thus in the catalogues of Arrow (1937) and of Blackwelder (1944) following Arrow, *vitulus* and *illatus* are listed both as synonyms of *Goniophileurus femoratus* (Burmeister) and also as valid species of *Phileurus;* actually, they have nothing to do with *femoratus*, and *vitulus* is a synonym of our common *illatus*.

Ritcher has studied larvae taken in the trunks of trees (*Dasylirion*) in Arizona. The species occurs fairly commonly in Arizona, very rarely in southern California and in northern Mexico and Lower California (Triunfo, July 7, Ross and Michelbacher). I have also seen a specimen some time ago, apparently of this species, taken from the La Brea tar pits in southern California, probably representing a specimen of the (?) Pleistocene period.

Phileurus castaneus Haldeman
Fig. 1, *d*

Phileurus castaneus Haldeman, 1843, p. 304; Casey, 1915, p. 270; Arrow, 1937, p. 89; Cazier, 1939, p. 170; Ritcher, 1944. p. 42 (larvae).
Phileurus valgus Olivier (nec Linnaeus), 1789, p. 43; Arrow, 1937, p. 89.
Phileurus texensis Casey, 1915, p. 268; Cazier, 1939, p. 170.
Phileurus sulcifer Casey, 1915, p. 269; Cazier 1939, p. 170.
Phileurus floridanus Casey, 1915, p. 270; Cazier, 1939, p. 170.
Phileurus carolinae Casey, 1915, p. 269; Cazier, 1939, p. 170.

Arrow in his 1937 catalogue lists four varieties of this species from the West Indies and South America. It is a fairly common species in the United States, ranging from Virginia through the Southern States and Florida and Texas into Mexico, and supposedly also Guatemala. Ritcher has reared the larva from a specimen collected in a cavity of a dead Basswood tree.

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ORNITHOLOGY.—*Note on the races of the black-throated sunbird,* Aethopyga saturata *(Hodgson).*[1] J. DELACOUR, American Museum of Natural History. (Communicated by HERBERT FRIEDMANN.)

While I was in Europe in the summer of 1947, I made a complete examination of the specimens of *Aethopyga saturata* preserved in the Museums of Paris and London at the instance of H. G. Deignan, who has recently revised the races of the species, using the material available in the United States. I found that the races stand as he has indicated in his recent paper (This JOURNAL **38**: 21–23. 1948) with one addition. Also new indications are supplied by the specimens in the Paris and London collections, many of which have been collected by me in Indochina. The metallic blue, or dull black, coloration of the middle of the throat of the males is an important characteristic, but it is not quite stable, and specimens varying in that way may be found apparently in several populations. I have listed the following ratios of metallic and dull throats in two subspecies from the specimens deposited in Paris and London.

Subspecies and locality	*Metallic throat*	*Dull throat*
sanguinipectus:		
Karenni	3 (including type)	1
Tenasserim	9	0
peteri:		
Southern Shan States	0	14
Haut Laos	2	9
Tongking	2	6

Even in specimens with a completely metallic blue throat the center is always somewhat duller than the sides, so that in some cases it is a question of degree and there is a gradation between the two ex-

[1] Received January 30, 1948.

tremes. Also there is a good deal of variation in the intensity and extent of the yellow of the underparts among specimens from Tongking and Haut Laos. Two males from Dakto, Central Annam, are similar to specimens from the Boloven Plateau and should be referred to *ochra*.

Mr. Deignan was unable to examine material from Bokor, southwestern Cambodia. This population is isolated on the Chaînes des Eléphants et des Cardamomes and has special characteristics. I propose to call it:

Aethopyga saturata cambodiana, n. subsp.

Type.—Brit. Mus. Nat. Hist. no. 1578, adult male, collected at Bokor, Cambodia, on December 12, 1927, by J. Delacour (original number 793).

Diagnosis.—Nearest to *ochra* Deignan (Bas Laos and Central Annam), differing in having the middle of throat usually metallic blue, not dull black, the mantle of a darker maroon red color and the abdomen grayer. Resembles *sanguinipectus* Walden (South Burma), but darker red on the mantle. In its dark mantle and metallic throat it approaches *johnsi* Robinson and Kloss (South Annam), which, however, is very distinct from all other races in the almost plain red color of the breast. Iris dark brown; bill black; legs blackish brown. Female similar to *petersi*, very yellow underneath.

Range.—The mountains of southwestern Cambodia and probably the border of Siam.

Specimens examined.—8 males, 3 females.

Remarks.—One of the males (Paris) has the center of throat dull black.

ORNITHOLOGY.—*Some races of the babbling thrush*, Malacocincla abbotti *Blyth*.[1]

H. G. Deignan, U. S. National Museum.

Despite the fact that this common babbler is generally admitted to show normal subspecific variation in the Malaysian Subregion, ornithological writers have consistently held that the nominate race ranges, without the least geographical change, from the eastern Himalayan foothills to Malaya and Indochine. Inasmuch as the rich material before me shows undeniable subspeciation, it must be supposed that lack of specimens from Arakan, the type locality of the species, has inhibited its proper study in the past.

It may be said at once that I have not myself seen a single topotype of *Malacocincla abbotti* and that all remarks to follow are based upon the premise that specimens from southwestern Siam and northern Tenasserim represent the Arakanese form—an assumption supported by careful comparison of these birds with the original description of Blyth (Journ. Asiat. Soc. Bengal 14, pt. 2: 601. Aug. 1845).

In my diagnoses of new subspecies, only fresh-plumaged adult examples have been employed, and "foxing" has been taken into account by comparison of birds of approximately the same date of collection. After these precautions, I still find it necessary to name three races from Siam alone. Their descriptions follow.

[1] Published by permission of the Secretary of the Smithsonian Institution. Received January 16, 1948.

1. **Malacocincla abbotti rufescentior**, n. subsp.

Type.—U. S. N. M. no. 330572, adult female, collected at Ban Tha Lo, southwest of Surat Thani or Ban Don (*ca.* lat. 9°05′ N., long. 99°15′ E.), peninsular Siam, on September 20, 1931, by Hugh M. Smith (original number 4982).

Diagnosis.—Separable in series from *M. a. abbotti* (as exemplified by birds from southwestern Siam and northern Tenasserim) by having the upperparts slightly more rufescent, and especially by having the underparts (except the white throat and abdomen) more strongly washed with a much brighter ferruginous.

Range.—Peninsular Siam (except Pattani Province) and southern Tenasserim.

Remarks.—*M. a. rufescentior* is distinguishable from *olivacea* of Pattani Province and Malaya by the same characters as separate it from *abbotti*. The material before me does not show any very obvious difference between *abbotti* and *olivacea*, although the latter seems to have the upperparts the least bit darker in tone; larger series would probably show this better.

Twenty-four winter-taken adults of *rufescentior* have been examined.

2. **Malacocincla abbotti obscurior,** n. subsp.

Type.—U. S. N. M. no. 333912, adult male, collected at Khao Sa Bap (lat. 12°35′ N., long. 102°15′ E.), Chanthaburi Province, southeastern Siam, on October 25, 1933, by Hugh M. Smith (original number 6545).

Diagnosis.—Separable in series from *M. a. rufescentior* by having the coloration of the crown, especially anteriorly, darker and more olivaceous; by having the remaining upperparts equally rufescent, but decidedly deeper in tone; and by having the rufescent of the underparts (excepting the white throat and abdomen) slightly brighter and deeper.

Range.—Southeastern Siam.

Remarks.—Twenty-five winter-taken adults of *obscurior* have been examined.

3. **Malacocincla abbotti williamsoni,** n. subsp.

Type.—U. S. N. M. no. 324357, adult male, collected at Sathani Pak Chong, eastern Siam at lat. 14°40′ N., long. 101°25′ E., on November 16, 1929, by Hugh M. Smith (original number 3457).

Diagnosis.—Like *M. a. obscurior* in the dark coloration of the crown but easily distinguishable from it in series by having the remaining upperparts olivaceous brown, but slightly suffused with rufescent, and by having the underparts (except the white throat and abdomen) more lightly washed with a paler ferruginous.

From *M. a. abbotti*, which it resembles beneath, *williamsoni* is separable by the deeper tone of the more olivaceous-brown upperparts and the darker coloration of the crown.

Range.—Eastern Siam and Laos (Vientiane).

Remarks.—This race is named in honor of Sir Walter J. F. Williamson, C.M.G., the well-known student of Siamese ornithology.

Eleven winter-taken adults of *williamsoni* have been examined.

ZOOLOGY.—*Two new millipeds of Jamaica.*[1] H. F. LOOMIS, Coconut Grove, Fla.

Late in January and early in February, 1937, Dr. E. A. Chapin, curator of insects, United States National Museum, collected insects and members of lower groups in Jamaica. The millipeds included in this collection were sent to me for identification, there being eight species of which two appear to be undescribed, one representing a new generic type. These two new millipeds are here described and the previously known species in the collection listed. All specimens have been deposited in the National Museum.

Glomeridesmus angulosus, n. sp.

One male (type) and six other specimens in bottle labeled only "Sifting fern gully, Feb. 2," but probably collected at Moneague, where other collecting was done the same day.

Diagnosis.—This is the smallest West Indian species of the genus and has the posterior corners of more of the caudal segments produced into acute angles than any other species. The last male legs also are distinctive.

Description.—Length of largest specimen, a female, with 21 segments, 4 mm, width 1 mm; largest male, with 20 segments, 3 mm long. The generally dark color of living animals probably is almost entirely derived from the internal organs showing through the quite transparent and colorless body wall noticeable in preserved specimens.

The pit behind each antenna is circular and not opened on any side, nor is the antennal socket opened behind or below although there is a depression below it as in the Haitian *G. jenkinsi* Loomis.

From segment 12 or 13 to segment 19 inclusive the posterior corners are increasingly produced into acute angles as shown in Fig. 1.

Basal joint of the legs with posterior margin minutely serrate. Pleurae with about three transverse ridges in front, the back margin smooth but with 6 to 8 minute, short, projecting setae; inner posterior corner acute. Penultimate legs of male with basal joints directed outward, the three terminal ones bent caudad. Last male legs with only the two terminal joints projecting beyond the penultimate legs, modified as shown in Fig. 2.

Siphonophora robusta Chamberlin

A female, apparently of this species from Moneague, station 370, February 2.

[1] Received January 16, 1948.

Rhinocricus sabulosus Pocock

A female from Moneague, station 370, February 2, and several specimens from "under dung" at Mocho, February 16.

Rhinocricus solitarius Pocock

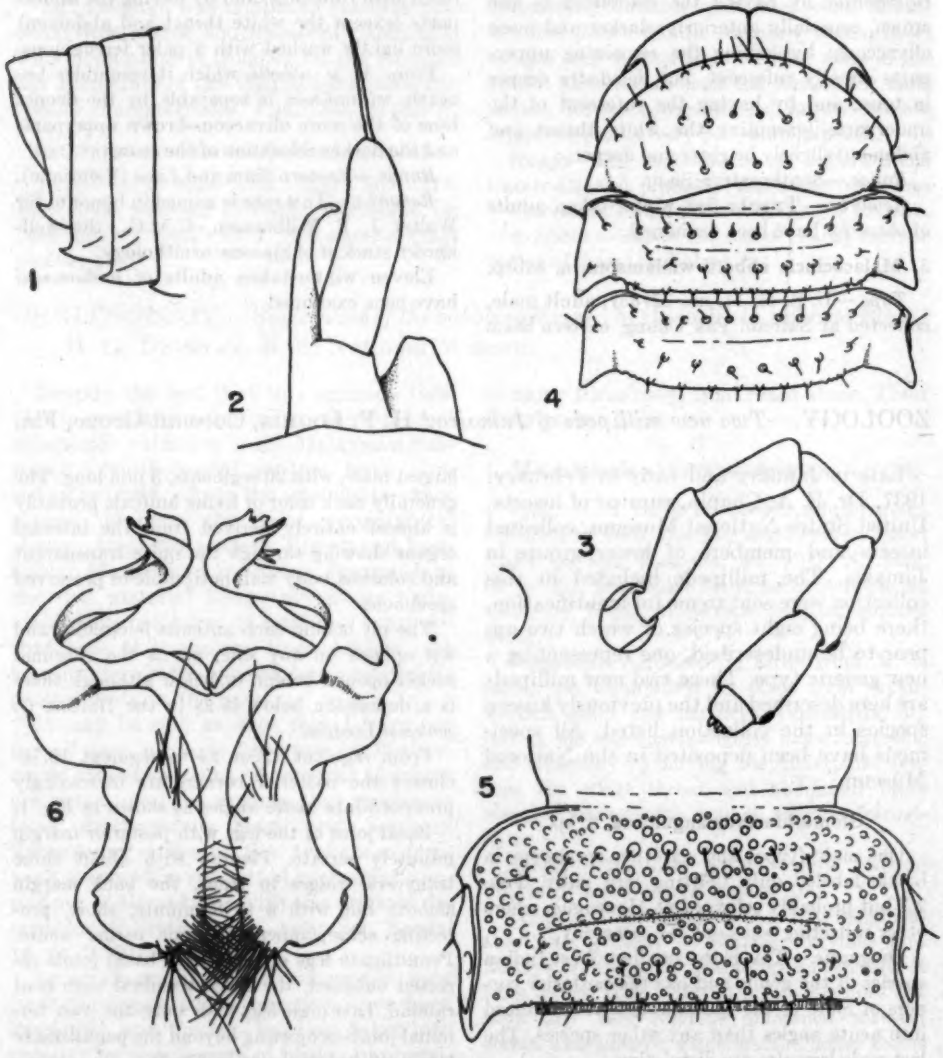
A male collected with *R. sabulosus* above.

Rhinocricus sp.

A young specimen from near White Horses, station 386, February 6.

Spirostrophus naresi (Pocock)

Numerous specimens from Bath St. Thomas, February 6 and 8.



FIGS. 1–2.—*Glomeridesmus angulosus*, n. sp.: 1, Segments 16 to 20, lateral view; 2, two apical joints of last male leg on left side, ventral view over penultimate leg.

FIGS. 3–6.—*Xaymacia granulata*, n. sp.: 3, Antenna and part of opposite socket; 4, head and first penultimate three segments, the nonsetiferous tubercles not shown; 5, segment 9 of male showing typical dorsal sculpture; 6, gonopods, ventral view.

Xaymacia, n. gen.

Genotype.—Xaymacia granulata, n. sp.

Diagnosis.—From the shape of the gonopods it does not appear that this genus has any close relatives in the known chelodesmid fauna of the West Indies or the mainland surrounding the Caribbean area. The ornamentation of the dorsum is not duplicated in other members of the family in the region.

Description.—Body of the size and proportions of the common *Orthomorpha coarctata* (Saussure) with which species specimens were collected in several localities. Males more slender and with the dorsum flatter than females. Dorsum thickly granulate in addition to three transverse series of slightly larger setose tubercles on segments 1 to 19, inclusive.

Head large, as wide as segment 1; a strong sulcus on the vertex; antennae separated by little more than the diameter of one of the sockets, geniculate at joint 4; joints 5 and 6 with a group of sensory hairs on the outer side near apex.

Produced posterior corners of lateral keels, from segment 2 to 18 inclusive, subequal in size. Pore formula normal, the pores opening outward from the margin of the carinae. Sterna sparsely hispid.

Gonopods with the apical half of the posterior division slender, pointed, and curving behind and partly obscured by the anterior division which is biramose and with its apical half in a sigmoid curve.

The generic name is in reference to the old name "Xaymaca" from which the modern name of Jamaica was derived.

Xaymacia granulata, n. sp.

From January 28 to February 8, 1937, numerous specimens were collected at the following localities: Caymanas, along Rio Cobre, (male type); Annotto Bay; Half Way Tree; Hope Gardens; Bath St. Thomas.

Description.—Length 16 to 18 mm; body parallel-sided from segment 1 to 16; males definitely more slender than females and the dorsum flatter, nearly horizontal; general size and color very similar to *Orthomorpha coarctata* (Saussure)

Living color dark brown except for the corners of segment 1 and the lateral carinae of succeeding segments which are light yellow, the color being restricted to the outer margin of the carina at the front of each segment but broadening to include the entire posterior corner; last segment wholly brown; sterna, legs, preanal scale, and the anal valves colorless.

Head almost as wide as remainder of body; strongly and evenly inflated, subglobose, with a very definite sulcus extending across the vertex to between the antennae; the vertex shining, glabrous behind, sparsely and finely hispid in front, the remainder of the head much more densely hispid with erect hairs varying in length from very short to others several times as long. Antennae close together near the front of the head, separated by little more than the diameter of one socket, shaped as shown in Fig. 3; joints 5 and 6 each with a small area of sensory hairs near apex on the outer side.

First segment semicircular, strongly convex, with the posterior corners depressed, thin, horizontal, rather acute but not produced backward; surface densely scattered with small vesiclelike granules as high as broad, and three transverse rows of slightly larger setiferous granules, 12 of which are along the anterior margin, 10 in the median row and 8 to 10 somewhat in advance of the posterior margin; a single seta projects outward from the margin just in advance of the posterior corner.

Ensuing segments with granules and transverse rows of setiferous tubercles similar to those of segment 1; a pronounced transverse sulcus crosses the middle of each segment and the lateral carinae have one or two setae projecting outward from the outer margin (Fig. 4). Second segment with the outer margin of the keels slightly longer than on ensuing ones, the posterior corners produced backward in the same degree which remains uniform to segment 18, corners of segment 19 reduced to half size; from segment 5 backward the outer margin of the keels thickened and containing an elongate impressed area opening outward, this being much broader in the poriferous keels (Fig. 5). Pore formula normal.

Last segment short, conical, abruptly narrower at apex, the dorsal surface lacking granules except those bearing the setae, there being an anterior row of six of these and a posterior, subapical, row of four, the outermost actually being on the lateral surface.

Preanal scale large, triangular, the posterior margin of segment 19 just in front of it with 6 to

10 marginal setae. Anal valves moderately inflated, the margins thinly elevated.

Sterna sparsely hispid with long erect hairs. Sterna of fourth male legs with two rather large conical tubercles, other sterna and legs normal. Gonopods as shown in Fig. 6.

Orthomorpha coarctata (Saussure)

Numerous specimens collected at Annotto Bay, January 30; Half Way Tree, January 28 and 31; Caymanas, on sandy beach along Rio Cobre, February 3.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

416TH MEETING OF BOARD OF MANAGERS

The 416th meeting of the Board of Managers, held in the Cosmos Club, March 15, 1948, was called to order at 8 P.M. by the President, DR. F. D. ROSSINI. Others present were: H. S. RAPPLEYE, W. L. SCHMITT, W. W. DIEHL, F. M. DEFANDORF, C. F. W. MUESEBECK, R. BAMFORD, W. A. DAYTON, F. B. SILSBEE, M. A. MASON, A. O. FOSTER, L. A. ROGERS, C. L. GARNER, C. L. GAZIN, and, by invitation, H. E. MCCOMB, R. J. SEEGER, and L. V. JUDSON.

The President announced the appointment of a Committee on Science Legislation: J. E. GRAF, Chairman, A. T. MCPHERSON, W. W. RUBEY.

It was reported that the Executive Committee had agreed to accept an invitation to join with the Library of Congress, the American Council of Learned Societies, and the Foundation for Integrated Education in cosponsoring a memorial meeting in honor of the late Alfred North Whitehead at the Library of Congress on Sunday, March 21, 1948.

The Executive Committee recommended to the Board that an allotment of $20 be made to the Membership Committee to cover expenses of office, including the preparation of mimeographed summaries of the new-member qualifications for presentation to the Board.

The Chairman of the Committee on Meetings, DR. R. J. SEEGER, announced that the March meeting would be given over to the Academy Award winners for 1947.

The secretary read the following report submitted by a committee appointed to consider the creation of an office of President-Elect, increase in the permitted number of members, and the addition of two standing committees:

The Committee met on 25 February 1948 in the office of Dr. Gazin at the National Museum to consider the questions referred to it by the Board of Managers, namely, the questions of creating the office of "President-Elect" of the Washington Academy of Sciences, of increasing the permitted number of members, and of adding the Committee on Awards for Scientific Achievement and the Committee on Grants-in-Aid for Research to the standing committees of the Board of Managers.

The Committee recommends the creation of the office of President-Elect to promote continuity of policies and objectives of the Academy by acquainting the income president with the current business and the administrative routine of the Academy.

The Committee regards with favor the proposal to raise the permitted number of members of the Academy since this would make possible an expansion of the Academy more nearly in proportion to the growth of Washington as a center of science, and would at the same time provide additional income for the Academy. However, the Committee feels that the increase in number should be a modest one. A large increase would create so many vacancies that there might be a danger of lowering the standards of admission of the Academy. The Committee suggests that the permitted number of active members be raised from 650 to 700 and the number of resident active members from 500 to 550. The Committee feels that such action would provide ample room for suitable candidates for several years to come, especially since there are at present about 20 vacancies in the Academy.

The Committee recommends increasing the number of standing committees of the Board of Managers from four to six to include the Committee on Awards for Scientific Achievement and the Committee on Grants-in-Aid for Research. Both of these committees have been standing committees in effect for the past several years.

[There followed a list of suggested changes in the Bylaws and Standing Rules to carry out these recommendations.]

The Board accepted the report and instructed the Secretary to submit to a vote of the membership the recommended changes in

the Bylaws, with the emendation that the increase in the number of members permitted in the Academy be changed from 50 to 100. Changes in the Standing Rules were accepted with one amendment. These changes are required to be presented at the next meeting of the Board for final approval.

Upon further discussion of the composition and duties of the various standing committees, it was voted that the present Special Committee that recommended the changes in the Bylaws look into the matter of the tenure of membership in the standing committees to consider the suggestion that some arrangement be made to permit a rotation or carry-over of a certain number of each committee to the succeeding year, in order to facilitate functioning of the committee and continuity in plans.

The Secretary reported the request by DR. O. E. MEINZER that H. FREEBORN JOHNSTON be reinstated as a member of the Academy. MR. Johnston resigned in 1939 as a result of ill health. The Board voted to reinstate him to membership.

The Secretary reported the death of DR. NELSON HORATIO DARTON, formerly with the Geological Survey, an original member of the Academy, on February 28, 1948; and of DR. WILLIAM RALPH MAXON, formerly curator of the U. S. National Herbarium, Smithsonian Institution, on February 25, 1948.

The Board approved the request of DR. OSCAR RIDDLE to be placed on the retired list, effective December 31, 1946.

The Senior Editor, DR. J. I. HOFFMAN, reported that he had read the monograph referred to the Board of Editors for comment and had found it to be in good order and worthy of publication. The monograph, *The Parasitic Birds of Africa*, by DR. HERBERT FRIEDMANN, was then referred to the new Committee on Monographs for its recommendations. DR. HOFFMAN then brought up the question of the proposed index to the first 40 volumes of the JOURNAL, and after some discussion the President was authorized to appoint a committee to consider the index and make recommendations on its publication.

The Board accepted the nomination of DR. T. DALE STEWART as a Vice-President of the Academy representing the Anthropological Society, replacing DR. W. N. FENTON who withdrew from this office because of his election to the Board of Managers.

Item 9 of the recommendations of the Committee to consider "various matters pertaining to the JOURNAL and its improvement," carried over from the unfinished business of the previous meeting of the Board, was again discussed. The President was authorized to appoint the committee recommended, i.e., to study the functions of the Academy and to formulate a program that will integrate these functions, including the JOURNAL. The Board requested that this committee make its report by January 1949.

The meeting was adjourned at 10:15 P.M.

C. L. GAZIN, *Secretary*

NEW MEMBERS OF THE ACADEMY

There follows a list of persons elected to membership in the Academy, by vote of its Board of Managers, since January 13, 1947, who have since qualified as members in accordance with the bylaws. (See also previous list in January 15, 1948, issue of the JOURNAL.) The bases for election are stated with the names of the new members.

RESIDENT

Elected January 13, 1947

JOSEPH P. E. MORRISON, zoologist, U. S. National Museum, in recognition of his scientific attainments in the field of malacology, especially for his studies on the taxonomy, anatomy, and biology of the fresh-water mollusks.

Elected October 6, 1947

EARLE K. PLYLER, physicist, National Bureau of Standards, in recognition of his work on the structure of molecules from infrared spectra, chemical analysis by infrared absorption measurements, and properties of matter as exhibited by characteristic absorption spectra.

Elected December 15, 1947

ROBERT C. COOK, biologist, managing editor of the Journal of Heredity, in recognition of his services to biology, in particular his long-time distinguished editorship of the Journal of Heredity.

IRA A. GOULD, JR., chemist, University of Maryland, in recognition of his studies on the chemistry of milk, especially of the chemical

changes brought about by the application of heat.

TIREY F. FORD, chemist, Bureau of Dairy Industry, in recognition of his contributions to the ultracentrifugal measurement of micellar sizes and in particular his researches on the particle size of the proteins of milk.

HAROLD H. SHEPARD, entomologist, U. S. Department of Agriculture, in recognition of his contributions to entomology, particularly the action of insecticides, the biology of stored products, insects, and the bibliography of the Hesperiidae.

PAUL R. MILLER, plant pathologist, Bureau of Plant Industry, Soils, and Agricultural Engineering, in recognition of his contributions to the science of plant pathology and in particular his researches on apple rusts and on plant-disease survey methods, including spore load studies, development of new techniques, epidemiological studies, etc.

W. GARDNER LYNN, biologist, Catholic University of America, in recognition of his studies in embryology and herpetology.

HUGH T. O'NEILL, botanist, Catholic University of America, in recognition of his contribution to systematic botany, especially the Cyperaceae and Arctic plants.

LEE LING, plant pathologist, Food and Agricultural Division, United Nations Organization, in recognition of his contributions to the mycology and plant pathology of China.

GEORGE D. ROCK, physicist, Catholic University of America, in recognition of his contributions to ultrasonics.

FRANCIS E. FOX, physicist, Catholic University of America, in recognition of his work in ultrasonics, particularly on the absorption of ultrasonic waves in liquids.

JOSEPH S. CALDWELL, physiologist, U. S. Department of Agriculture, in recognition of his studies in the physiology of fruit and vegetable processing.

FRANK L. CAMPBELL, entomologist, editor of the Scientific Monthly, in recognition of his researches in entomology, in particular the physiology of insects in relation to toxicology.

RICHARD S. DILL, engineer, Heating and Air Conditioning Section, National Bureau of Standards, in recognition of his outstanding research in the fields of heating, insulation, and air-conditioning of structures.

JOHN K. TAYLOR, chemist, National Bureau of Standards, in recognition of his work on electrode potentials, refractive index, and polarography.

J. BROOKES KNIGHT, paleontologist, U. S. National Museum, in recognition of his contributions to the knowledge of Paleozoic Gastropoda.

DORIS M. COCHRAN, zoologist, U. S. National Museum, in recognition of her scientific work in taxonomic herpetology, especially for the *Herpetology of Hispaniola*, U. S. National Museum Bulletin 177, 1941.

Elected January 12, 1948

JOHN C. EWERS, ethnologist, U. S. National Museum, in recognition of his research on the material culture and arts and crafts of the Plains Indians in historic times.

WALTER S. DIEHL, engineer, Bureau of Aeronautics, Department of the Navy, in recognition of his contributions to aerodynamics and to aeronautics.

ASHLEY B. GURNEY, entomologist, Bureau of Entomology and Plant Quarantine, in recognition of his contributions to the taxonomy of the Orthoptera, Corrodentia, Neuroptera, and Zoraptera.

HARRY A. BORTHWICK, botanist, Bureau of Plant Industry, Soils, and Agricultural Engineering, in recognition of his work in plant physiology and in particular his researches on photoperiodism in relation to plant morphology.

MARION W. PARKER, botanist, Bureau of Plant Industry, Soils, and Agricultural Engineering, in recognition of his work in plant physiology and especially on the relation of light and temperature to plant growth.

PHILIP BRIERLEY, plant pathologist, Bureau of Plant Industry, Soils, and Agricultural Engineering, in recognition of his contributions to plant pathology, particularly in clearing up the nature and complexity of the virus diseases of *Lilium longiflorum*.

WILBUR D. MCCLELLAN, plant pathologist, Bureau of Plant Industry, Soils, and Agricultural Engineering, in recognition of his work on use of fungicides and interaction of nutritives and fungicides in the pathogenicity of certain organisms.

PAUL C. MARTH, botanist, Bureau of Plant Industry, Soils, and Agricultural Engineering,

in recognition of his work in plant physiology, in particular his pioneering research on the effects of growth regulators on plants and fruits.

FLOYD F. SMITH, entomologist, Bureau of Entomology and Plant Quarantine, in recognition of his investigations of insects as vectors of viruses and the application of aerosols to insect enemies of ornamental plants.

NONRESIDENT

Elected January 13, 1947

AGESILAU A. BITANCOURT, biologist, Instituto Biológico São Paulo, Brazil, in recognition of his contributions to tropical researches in plant pathology, particularly in citrus diseases.

Elected December 15, 1947

JULIAN H. MILLER, plant pathologist, University of Georgia, Athens, Ga., in recognition of his researches in mycology, in particular his contributions on the comparative morphology and taxonomy of the Sphaeriales.

ERNEST H. VOLWILER, chemist, Abbott Laboratories, North Chicago, Ill., in recognition of his contributions to organic chemistry, particularly the synthesis of organic medicinals.

ANTHROPOLOGICAL SOCIETY

The Anthropological Society of Washington at its annual meeting held on January 7, 1948, elected the following officers: President, WILLIAM N. FENTON; Vice-President, W. MONTAGUE COBB: Secretary, MARSHALL T. NEWMAN: Treasurer, JOHN C. EWERS: Councilors to the Board of Managers, E. WYLLYS ANDREWS IV, STELLA L. DEIGNAN, GEORGE M. FOSTER, WILLIAM H. GILBERT, JR., GORDON R. WILLEY; Representative to the Washington Academy of Sciences, T. D. STEWART.

A report of the membership and activities of the Society since the last annual meeting follows:

Life members, 1; Active members, 62; Associate members, 20; Total, 83. This represents a decrease of six since last year.

The members elected during the year were: Active members: Dr. E. W. ANDREWS, Comdr. SYDNEY CONNOR, J. R. CALDWELL, DR. N. DATTA-MAJUMDER, DR. PHILIP DRUCKER, MISS E. C. DAVIS, DR. C. E. HUTCHINSON, DR. D. W. LOCKARD, DR. W. O. NEGHERBON, DR. PHILLEO NASH, DR. M. H. WATKINS, Associate member: Dr. GEORGE M. FOSTER.

The Society records its deep sense of loss at the death of DR. BEATRICE BICKEL, member since 1933.

Except for the joint meeting with the Washington Academy of Sciences at the Cosmos Club on January 16, 1947, all regular meetings were held at the U. S. National Museum. The Program Committee for the year comprised DR. MARSHALL T. NEWMAN, *chairman*, and DR. MARGARET LANTIS.

Titles of papers presented before the regular meetings of the Society were:

January 16, 1947, 739th meeting, WALDO R. WEDEL, *Archeology and the Missouri River development program* (slides; refreshments served by Washington Academy of Sciences).

February 18, 1947, 740th meeting, R. RUGGLES GATES, *Human ancestry from a geneticist's viewpoint* (slides).

March 18, 1947, 741st meeting, PRESTON HOLDER, *The Motilon Indians, an untouched tropical forest group in northwestern South America.* (Published in this JOURNAL 37: 417–427, 1947).

April 15, 1947, 742d meeting, W. MONTAGUE COBB, *The American Negro in the light of modern physical anthropology* (slides).

May 23, 1947, 743d meeting (joint meeting with the Medico-Chirurgical Society of the District of Columbia), WILTON M. KROGMAN, *Anthropology and race relations.*

October 21, 1947, 744th meeting, Father ERNST WORMS, *The natives of northwestern Australia—a contemporary picture of their language and culture* (sound color film).

November 5, 1947, 745th meeting, GEORGE M. FOSTER, *The People of Tzintzuntzan—a contemporary study of social and economic adjustment in Mexico* (color films).

December 3, 1947, 746th meeting, EUGENE C. WORMAN, JR., *The neolithic period in India—new evidence on early cultural movements in Asia.*

The Society voted to freeze the Perpetual Building fund at $2,000 and to subsequently add the interest to dues and other income for running expenses. In this way the scope of activities can be enlarged. It was decided also to govern annual expenditures by a budget estimate made at the start of each year.

The report of the Treasurer follows:

Income:

A.S.W. dues collected	$ 112.00	
Back dues (A.A.A.) collected to reimburse A.S.W. for carrying delinquents	5.00	
Interest, Perpetual Building Association	57.38	
Dividends, Washington Sanitary Improvement Co.	33.60	
Dividends, Washington Sanitary Housing Co.	12.00	
Interest, U. S. Savings Bond	12.50	
Sale of Old Series *Anthropologists*	7.60	
		$ 240.08

Expenditures:

A.A.A. dues paid for Secretary and one life member	10.00	
Expenses, speakers	60.00	
Dues, Inter-American Society of Anthropology and Geography	3.00	
Printing and mailing notices	77.03	
Incidental meeting expenses	24.00	
Miscellaneous expenses, Secretary and Treasurer	9.64	
		183.67
Balance		$ 56.41

Assets:

Funds invested in Perpetual Building Association (with interest to Dec. 31, 1947)	$1,956.50	
21 Shares Washington Sanitary Improvement Co. (par value $10 per share)	210.00	
2 Shares Washington Sanitary Housing Co. (par value $100 per share)	200.00	
U. S. Savings Bond, Series G	500.00	
Cash in bank	261.65	
Total as of December 31, 1947		$3,128.15
Total as of December 31, 1946		3,071.74
Increase		$ 56.41

Less bills outstanding:

To A.A.A. (Subscriptions to *American Anthropologist*):		
For 1 member, 3 years, 1948–50	$ 15.00	
For 1 member, 1 year, 1948	5.00	
		20.00
Net increase		$ 36.41

MARSHALL T. NEWMAN, *Secretary.*